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ENCYCLOPEDIA
OF
ENGINEERING

A Treatise on

BOILERS, STEAM ENGINES, THE LOCOMO
TIVE, ELECTRICITY, MACHINE SHOP
PRACTICE, AIR BRAKE PRACTICE,
ENGINEER'S CATECHISM, GAS,
OIL, TRACTION AND AUTO-
MOBILE MOTORS,
REFRIGERA-
TION, ETC.
ETC.

By

CALVIN F. SWINGLE, M. E.
EDITOR-IN-CHIEF

And a Corps of
ENGINEERS AND MECHANICAL AND ELECTRICAL
EXPERTS

SEVEN VOLUMES
Containing Thirty-five Hundred Pages and Fifteen
Hundred Illustrations

INTERNATIONAL SCHOOL OF ENGINEERING
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V. 3

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Introduction

THIS Encyclopedia has been compiled from the latest and most practical papers of the International School of Engineering, by Calvin F. Swingle and other authors. It is intended to furnish practical instruction in the subjects, covered in each volume, for those who are not in a position to take up a correspondence course or attend a School of Engineering. Each volume is complete in itself, and will be found to be of great practical value to the mechanic or student who desires to obtain the latest and best information on the subjects contained therein. Numerous practical examples are given in each volume, which help to bring out the fundamental principles involved and also fix the essential points in the reader's mind.

Experience in the workshop, laboratory and classroom of years duration have been necessary in the preparation of the different sections of this work, and the subjects contained in each, have been tested by actual use as to their practical value to the person who desires to be up in the latest and best shop or engine-room practice. This Encyclopedia has been compiled with the idea of making it of value to those who are not in a position to benefit themselves by a technical school course.

THE
YOUNG ENGINEERS' GUIDE

CHAPTER I.

BUYING AN ENGINE.

There are a great many makes of good engines on the market to-day, and the competition is so keen that no engine maker can afford to turn out a very poor engine. This is especially true of traction engines. The different styles and types all have their advantages, and are good in their way. For all that, one good engine may be valueless for you, and there are many ways in which you may make a great mistake in purchasing an engine. The following points will help you to choose wisely:

1. Consider what you want an engine for. If it is a stationary engine, consider the work to be done, the space it is to occupy, and what conveniences will save your time. Remember, TIME IS MONEY, and that means that SPACE IS ALSO MONEY. Choose the kind of engine that will be most convenient for the position in which you wish to place it and the purpose or purposes for which you wish to use it. If buying a traction engine, consider also the roads and an engine's pulling qualities.

2. If you are buying a traction engine for threshing, the first thing to consider is FUEL. Which will be cheapest for you, wood, coal or straw? Is economy of fuel much of an object with you—one that will justify you in greater care and more scientific study of your engine? Other things being equal, the direct flue, firebox,

locomotive boiler and simple engine will be the best, since they are the easiest to operate. They are not the most economical under favorable conditions, but a return flue boiler and a compound engine will cost you far more than the possible saving of fuel unless you manage them in a scientific way. Indeed, if not rightly managed they will waste more fuel than the direct flue locomotive boiler and the simple engine.

3. Do not try to economize on the size of your boiler, and at the same time never get too large an engine. If a 6-horse power boiler will just do your work, an 8-horse power will do it better and more economically, because you won't be overworking it all the time. Engines should seldom be crowded. At the same time you never know when you may want a higher capacity than you have, or how much you may lose by not having it. Of course you don't want an engine and boiler that are too big, but you should always allow a fair margin above your anticipated requirements.

4. Do not try to economize on appliances. You should have a good pump, a good injector, a good heater, an extra steam gauge, an extra fusible plug ready to put in, a flue expander and a beader. You should also certainly have a good force pump and hose to clean the boiler, and the best oil and grease you can get. Never believe the man who tells you that something not quite the best is just as good. You will find it the most expensive thing you ever tried—if you have wit enough to find out how expensive it is.

5. If you want my personal advice on the proper engine to select for various purposes, I should say by all means get a gasoline engine for small powers about the farm, such as pumping, etc. It is the quickest to start, by far the most economical to operate, and the simplest to manage. The day of the small steam engine is past and will never return, and ten gasoline engines of this kind are sold for every steam engine put out. If you want a traction engine for threshing, etc., stick to steam. Gasoline engines are not very good hill climbers because the application of power is not steady enough; they are

not very good to get out of mud holes with for the same reason, and as yet they are not perfected for such purposes. You might use a portable gasoline engine, however, though the application of power is not as steady as with steam and the flywheels are heavy. In choosing a traction steam engine, the direct flue locomotive boiler and simple engine, though theoretically not so economical as the return flue boiler and compound engine, will in many cases prove so practically because they are so much simpler and there is not the chance to go wrong with them that there is with the others. If for any reason you want a very quick steamer, buy an upright. If economy of fuel is very important and you are prepared to make the necessary effort to secure it, a return flue boiler will be a good investment, and a really good compound engine may be. Where a large plant is to be operated and a high power constant and steady energy is demanded, stick to steam, since the gasoline engines of the larger size have not proved so successful, and are certainly by no means so steady; and in such a case the exhaust steam can be used for heating and for various other purposes that will work the greatest economy. For such a plant choose a horizontal tubular boiler, set in masonry, and a compound engine (the latter if you have a scientific engineer).

In general, in the traction engine, look to the convenience of arrangement of the throttle, reverse lever, steering wheel, friction clutch, independent pump and injector, all of which should be within easy reach of the footboard, as such an arrangement will save annoyance and often damage when quick action is required.

The boiler should be well set; the firebox large, with large grate surface if a locomotive type of boiler is used, and the number of flues should be sufficient to allow good combustion without forced draft. A return flue boiler should have a large main flue, material of the required 5-16-inch thickness, a mud drum, and four to six handholes suitably situated for cleaning the boiler. There should be a rather high average boiler pressure, as high pressure is more economical than low. For a simple engine, 80 pounds and for a compound 125 pounds should be minimum.

A stationary engine should have a solid foundation built by a mason who understands the business, and should be in a light, dry room—never in a dark cellar or a damp place.

Every farm traction engine should have a friction clutch.

CHAPTER II.

BOILERS.

The first boilers were made as a single cylinder of wrought iron set in brick work, with provision for a fire under one end. This was used for many years, but it produced steam very slowly and with great waste of fuel.

The first improvement to be made in this was a fire flue running the whole length of the interior of the boiler, with the fire in one end of the flue. This fire flue was entirely surrounded by water.

Then a boiler was made with two flues that came together at the smoke-box end. First one flue was fired and then the other, alternately, the clear heat of one burning the smoke of the other when it came into the common passage.

The next step was to introduce conical tubes by which the water could circulate through the main fire flue (Galloway boiler).

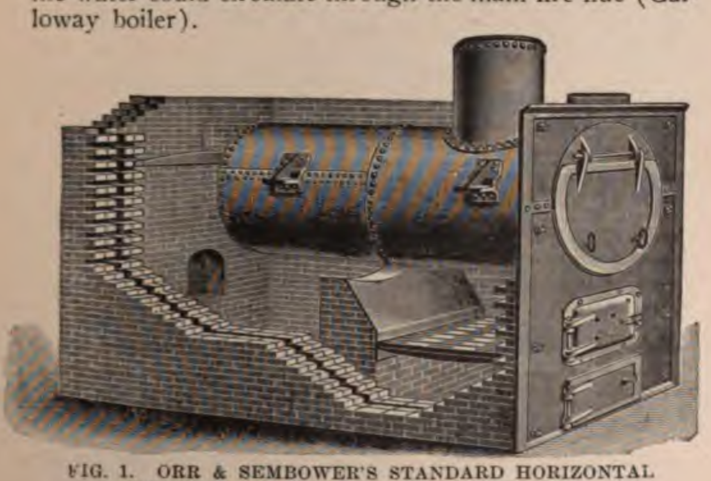


FIG. 1. ORR & SEMBOWER'S STANDARD HORIZONTAL BOILER, WITH FULL-ARCH FRONT SETTING.

heating section. To make
ally, the heating section must

The stationary boiler now most commonly used is cylindrical, the fire is built in a brick furnace under the sheet and returns through fire tubes running the length of the boiler. (Fig. 1.)

LOCOMOTIVE FIRE TUBE TYPE OF BOILER.

The earliest of the modern steam boilers to come into use was the locomotive fire tube type, with a special firebox. By reference to the illustration (Fig. 2) you will see that the boiler cylinder is perforated with a number of tubes from 2 to 4 inches in diameter running from the large firebox on the left, through the boiler cylinder filled with water, to the smoke-box on the right, above which the smokestack rises.

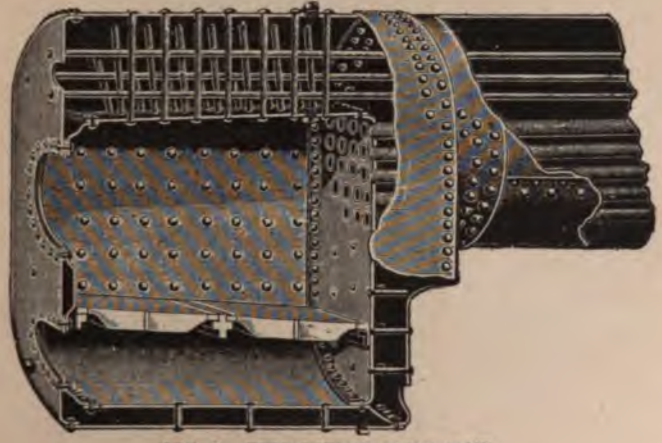


FIG. 3. THE HUBER FIRE BOX.

It will be noticed that the walls of the firebox are double, and that the water circulates freely all about the firebox as well as all about the fire tubes. The inner walls of the firebox are held firmly in position by stay bolts, as will be seen in Fig. 3, which also shows the position of the grate.

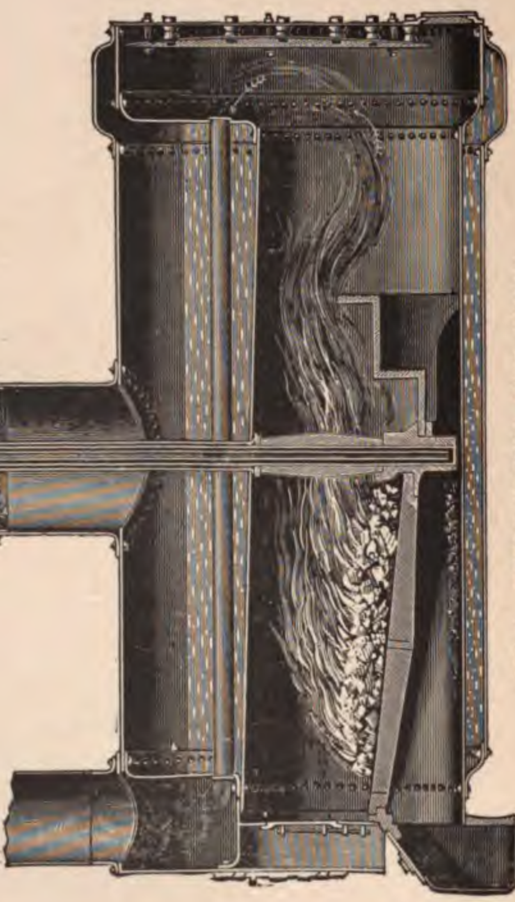


FIG. 4. HUBER RETURN FLUE BOILER.

RETURN FLUE TYPE OF BOILER.

The return flue type of boiler consists of a large central fire flue running through the boiler cylinder to the smoke box at the front end, which is entirely closed. The smoke passes back through a number of small tubes, and the smokestack is directly over the fire at the rear of the boiler, though there is no communication between the fire at the rear of the boiler and it except through the main flue to the front and back through the small return flues. Fig. 4 illustrates this type of boiler, though it shows but one return flue. The actual number may be seen by the sectional view in Fig. 5.

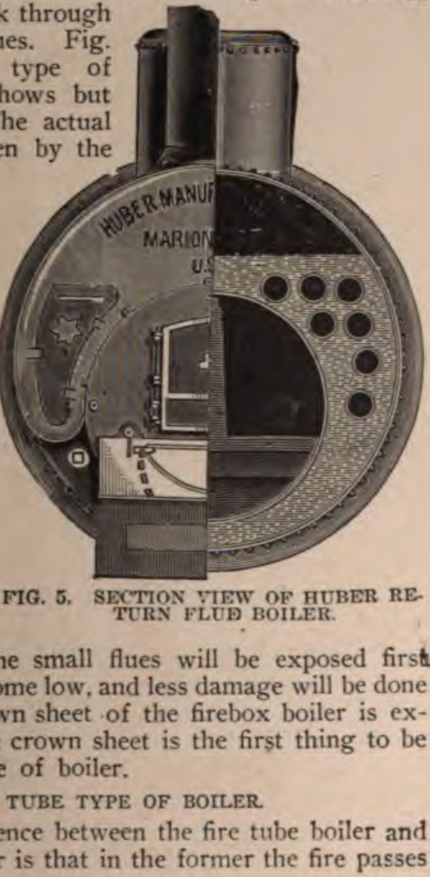


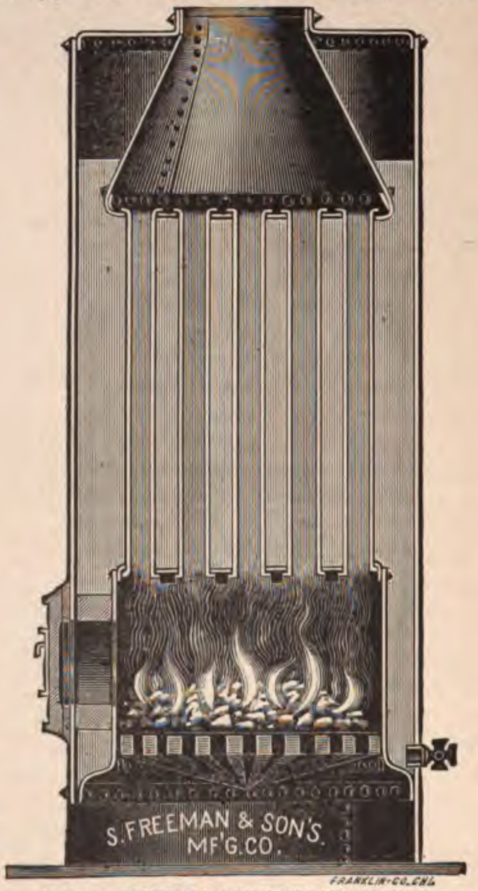
FIG. 5. SECTION VIEW OF HUBER RETURN FLUE BOILER.

The fire is built in one end of the main flue, and is entirely surrounded by water, as will be seen in the illustration. The long passage for the flame and heated gases enables the water to absorb a maximum amount of the heat of combustion. There is also an element of safety in this boiler in that the small flues will be exposed first should the water become low, and less damage will be done than if the large crown sheet of the firebox boiler is exposed, and this large crown sheet is the first thing to be exposed in that type of boiler.

WATER TUBE TYPE OF BOILER.

The special difference between the fire tube boiler and the water tube boiler is that in the former the fire passes through the tubes, while in the latter the water is in the tubes and the fire passes around them.

In this type of boiler there is an upper cylinder (or more than one) filled with water; a series of small tubes running at an angle from the front or fire door end of the upper cylinder to a point below and back of the grates,



FRANKLIN-CO. ENG.

FIG. 6. FREEMAN VERTICAL BOILER.

where they meet in another cylinder or pipe, which is connected with the other end of the upper cylinder. The portions of the tubes directly over the fire will be hottest, and the water here will become heated and rise to the front end of the upper cylinder, while to fill the space left, colder water is drawn in from the back pipe, from the rear end of the upper cylinder, down to the lower ends of the water tubes, to pass along up through them to the front end again.

This type of boiler gives great heating surface, and since the tubes are small they will have ample strength with much thinner walls. Great freedom of circulation is important in this type of boiler, there being no contracted cells in the passage. This is not adapted for a portable engine.

UPRIGHT OR VERTICAL TYPE OF BOILER.

In the upright type of boiler the boiler cylinder is placed on end, the fire is built at the lower end, which is a firebox surrounded by a water jacket, and the smoke and gases of combustion rise straight up through vertical fire flues. The amount of water carried is relatively small, and the steam space is also small, while the heating surface is relatively large if the boiler is sufficiently tall. You can get up steam in this type of boiler quicker than in any other, and in case of the stationary engine, the space occupied is a minimum. The majority of small stationary engines have this type of boiler, and there is a traction engine with upright boiler which has been widely used, but it is open to the objection that the upper or steam ends of the tubes easily get overheated and so become leaky. There is also often trouble from mud and scale deposits in the water leg, the bottom area of which is very small.

DEFINITION OF TERMS USED IN CONNECTION WITH BOILERS.

Shell—The main cylindrical steel sheets which form the principal part of the boiler.

Boiler-heads—The ends of the boiler cylinder.

Tube Sheets—The sheets in which the fire tubes are inserted at each end of the boiler.

Fire-box—A nearly square space at one end of a boiler, in which the fire is placed. Properly it is surrounded on all sides by a double wall, the space between the two shells of these walls being filled with water. All flat surfaces are securely fastened by stay bolts and crown bars, but cylindrical surfaces are self-bracing.

Water-leg—The space at sides of fire-box and below it in which water passes.

Crown-sheet—The sheet of steel at the top of the fire-box, just under the water in the boiler. This crown sheet is exposed to severe heat, but so long as it is covered with water, the water will conduct the heat away, and the metal can never become any hotter than the water in the boiler. If, however, it is not covered with water, but only by steam, it quickly becomes overheated, since the steam does not conduct the heat away as the water does. It may become so hot it will soften and sag, but the great danger is that the thin layer of water near this over-heated crown sheet will be suddenly turned into a great volume of steam and cause an explosion. If some of the pressure is taken off, this overheated water may suddenly burst into steam and cause an explosion, as the safety valve blows off, for example (since the safety valve relieves some of the pressure).

Smoke-box—The space at the end of the boiler opposite to that of the fire, in which the smoke may accumulate before passing up the stack in the locomotive type, or through the small flues in the return type of boiler.

Steam-dome—A drum or projection at the top of the boiler cylinder, forming the highest point which the steam can reach. The steam is taken from the boiler through piping leading from the top of this dome, since at this point it is least likely to be mixed with water, either through foaming or shaking up of the boiler. Even under normal conditions the steam at the top of the dome is drier than anywhere else.

Mud-drum—A cylindrical-shaped receptacle at the bottom of the boiler similar to the steam-dome at the top, but not so deep. Impurities in the water accumulate here, and it is of great value on a return flue boiler. In a locomotive boiler the mud accumulates in the water leg, below the firebox.

Man-holes—Are large openings into the interior of a boiler, through which a man may pass to clean out the inside.

Hand-holes—Are smaller holes at various points in the boiler into which the nozzle of a hose may be introduced for cleaning out the interior. All these openings must be securely covered with steam-tight plates, called man-hole and hand-hole plates.

A boiler jacket—A non-conducting covering of wood, plaster, hair, rags, felt, paper, asbestos or the like, which prevents the boiler shell from cooling too rapidly through radiation of heat from the steel. These materials are usually held in place against the boiler by sheet iron. An intervening air-space between the jacket and the boiler shell will add to the efficiency of the jacket.

A steam-jacket—A space around an engine cylinder or the like which may be filled with live steam so as to keep the interior from cooling rapidly.

Ash-pit—The space directly under the grates, where the ashes accumulate.

Dead-plates—Solid sheets of steel on which the fire lies the same as on the grates, but with no openings through to the ash-pit. Dead-plates are sometimes used to prevent cold air passing through the fire into the flues, and are common on straw-burning boilers. They should seldom if ever be used on coal or wood firing boilers.

Grate Surface—The whole space occupied by the grate-bars, usually measured in square feet.

Forced Draft—A draft produced by any means other than the natural tendency of the heated gases of combustion to rise. For example, a draft caused by letting steam escape into the stack.

Heating Surface—The entire surface of the boiler exposed to the heat of the fire, or the area of steel or iron sheeting or tubing, on one side of which is water and on the other heated air or gases.

Steam-space—The cubical contents of the space which may be occupied by steam above the water.

Water-space—The cubical contents of the space occupied by water below the steam.

Diaphragm-plate—A perforated plate used in the domes of locomotive boilers to prevent water dashing into the steam supply pipe. A dry-pipe is a pipe with small perforations, used for taking steam from the steam-space, instead of from a dome with diaphragm-plate.

THE ATTACHMENTS OF A BOILER.*

Before proceeding to a consideration of the care and management of a boiler, let us briefly indicate the chief working attachments of a boiler. Unless the nature and uses of these attachments are fully understood, it will be impossible to handle the boiler in a thoroughly safe and scientific fashion, though some engineers do handle boilers without knowing all about these attachments. Their ignorance in many cases costs them their lives and the lives of others.

The first duty of the engineer is to see that the boiler is filled with water. This he usually does by looking at the glass water-gauge.

TWO-ROD WATER GAUGE.

THE WATER GAUGE AND COCKS.

There is a cock at each end of the glass tube. When these cocks are open the water will pass through the lower into the glass tube, while steam comes through the other. The level of the water in the gauge will then be the same as the level of the water in the boiler, and the water should never fall out of sight below the lower end of the glass, nor rise above the upper end.

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*Unless otherwise indicated, cuts of fittings show those manufactured by the Lunkenheimer Co., Cincinnati, Ohio.

Below the lower gauge cock there is another cock used for draining the gauge and blowing it off when there is a pressure of steam on. By occasionally opening this cock, allowing the heated water or steam to blow through it, the engineer may always be sure that the passages into the water gauge are not stopped up by any means. By closing the upper cock and opening the lower, the passage into the lower may be cleared by blowing off the drain cock; by closing the lower gauge cock and opening the upper the passage from the steam space may be cleared and tested in the same way when the drain cock is opened. If the glass breaks, both upper and lower gauge cocks should be closed instantly.

In addition to the glass water gauge, there are the try-cocks for ascertaining the level of the water in the boiler. There should be two to four of these. They open directly out of the boiler sheet, and by opening them in turn it is possible to tell approximately where the water stands. There should be one cock near the level of the crown sheet, or slightly above it, another about the level of the lower gauge cock, another about the middle of the gauge, another about the level of the upper gauge, and still another, perhaps, a little higher. But one above and one below the water line will be sufficient. If water stands above the level of the cock, it will blow off white mist when opened; if the cock opens from steam-space, it will blow off blue steam when opened.

GAUGE OR TRY COCK.

The try-cocks should be opened from time to time in order to be sure the water stands at the proper level in the boiler, for various things may interfere with the working of the glass gauge. Try-cocks are often called gauge cocks.

TRY COCK.

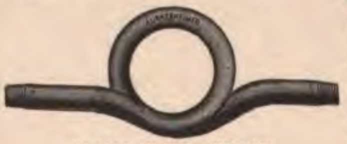
THE STEAM GAUGE.

The steam gauge is a delicate instrument arranged so as to indicate by a pointer the pounds of pressure which the steam is exerting within the boiler. It is extremely important, and a defect in it may cause much damage.

The steam gauge was invented in 1849 by Eugene Bourdon, of France. He discovered that a flat tube bent in a simple curve, held fast at one end, would expand and contract if made of proper spring material, through the pressure of the water within the tube. The free end operates a clock-work that moves the pointer.

PRESSURE GAUGE.

It is important that the steam gauge be attached to the boiler by a siphon, or with a knot in the tube, so that the steam may operate on water contained in the tube, and the water cannot become displaced by steam, since steam might interfere with the correct working of the gauge by expanding the gauge tube through its excessive heat.



STEAM GAUGE SIPHON.

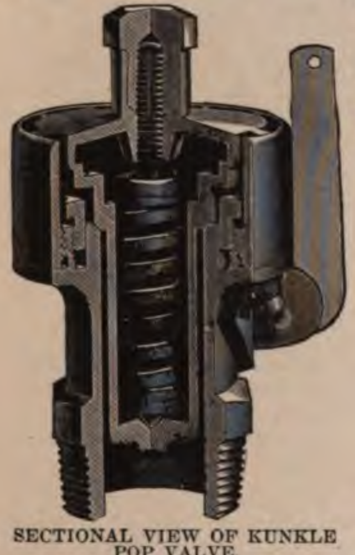
Steam gauges frequently get out of order, and should be tested occasionally. This may conveniently be done by attaching them to a boiler which has a correct gauge already on it. If both register alike, it is probable that both are accurate.

There are also self-testing steam gauges. With all pressure off, the pointer will return to O. Then a series of weights are arranged which may be hung on the gauge and cause the pointer to indicate corresponding numbers. The chief source of variation is in the loosening of the indicator needle. This shows itself usually when the pressure is off and the pointer does not return exactly to zero.

FRONT CYLINDER COCK.

SAFETY VALVE.

The safety valve is a valve held in place by a weighted lever* or by a spiral spring (on traction engines) or some similar device, and is adjustable by a screw or the like so that it can be set to blow off at a given pressure of steam, usually the rated pressure of the boiler, which on traction engines is from 110 to 130 pounds. The valve is supplied with a handle by which it can be opened, and it should be opened occasionally to make sure it is working all right. When it blows off the steam gauge should be noted to see that it agrees with the pressure for which the safety valve was set. If they do not agree, something is wrong; either the safety valve does not work freely, or the steam gauge does not register accurately.



SECTIONAL VIEW OF KUNKLE POP VALVE.

SAFETY VALVE.

The cut shows the Kunkle safety valve. To set it, unscrew the jam nut and apply the key to the pressure screw. For more pressure, screw down; for less, unscrew. After having the desired pressure, screw the jam nut down tight on the pressure screw. To regulate the opening and closing of the valve, take the pointed end of a file and apply it to the teeth of the regulator. If valve closes with too much boiler pressure, move the regulator to the left. If with too little, move the regulator to the right.

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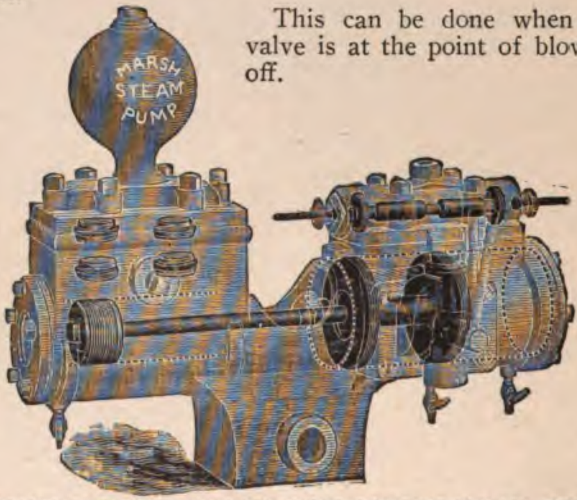
*This kind of safety valve is now being entirely discarded as much more dangerous than the spring or pop valve.

This can be done when the valve is at the point of blowing off.



PHANTOM VIEW OF MARSH INDEPENDENT STEAM PUMP.

Other types of valves are managed in a similar way, and exact directions will always be furnished by the manufacturers.

FILLING THE BOILER WITH WATER.

There are three ways in which a boiler is commonly filled with water.

First, before starting a boiler it must be filled with water by hand, or with a hand force-pump. There is usually a filler plug, which must be taken out, and a funnel can be attached in its place. Open one of the gauge cocks to let out the air as the water goes in.

When the boiler has a sufficient amount of water, as may be seen by the glass water gauge, replace the filler plug. After steam is up the boiler should be supplied with water by a pump or injector.

THE BOILER PUMP.

There are two kinds of pumps commonly used on traction engines, the Independent pump, and the Cross-head pump.

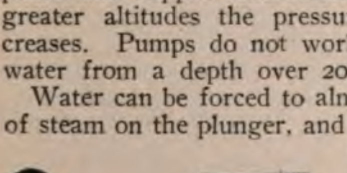
The Independent pump is virtually an independent engine with pump attached. There are two cylinders, one receiving steam and conveying force to the piston; the other a water cylinder, in which a plunger works, drawing the water into itself by suction and forcing it out through the connection pipe into the boiler by force of steam pressure in the steam cylinder.

It is to be noted that all suction pumps receive their water by reason of the pressure of the atmosphere on the surface of the water in the supply tank or well. This atmospheric pressure is about 15 pounds to the square inch, and is sufficient to support a column of water 28 to 33 feet high, 33 feet being the height of a column of water which the atmosphere will support theoretically at about sea level. At greater altitudes the pressure of the atmosphere decreases. Pumps do not work very well when drawing water from a depth over 20 or 22 feet.

STRAIGHT GLOBE VALVE.

Water can be forced to almost any height by pressure of steam on the plunger, and it is taken from deep wells by deep well pumps, which suck the water 20 to 25 feet, and force it the rest of the way by pressure on a plunger.

The amount of water pumped is regulated by a cock or globe valve in the suction pipe.



ANGLE GLOBE VALVE.

A Cross-head boiler pump is a pump attached to the cross-head of an engine. The force of the engine piston is transmitted to the plunger of the pump.

VALVE WITH INTERNAL SCREW.

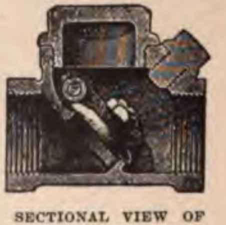
The pump portion works exactly the same, whether of the independent or cross-head kind.

The cut represents an independent pump that uses the exhaust steam to heat the water as it is pumped (Marsh pump).

Every boiler feed-pump must have at least two check valves.

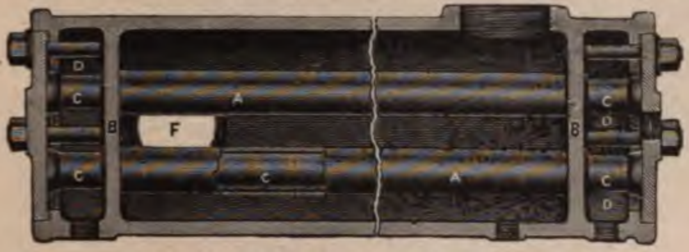
A check valve is a small swinging gate valve (usually) contained in a pipe, and so arranged that when water is flowing in one direction the valve will automatically open to let the water pass, while if water should be forced in the other direction, the valve will automatically close tight and prevent the water from passing.

There is one check valve in the supply pipe which conducts the water from the tank or well to the pump cylinder. When the plunger is drawn back or raised, a vacuum is created in the pump cylinder and the outside atmospheric pressure forces water through the supply pipe into the cylinder, and the check valve opens to let it pass. When the plunger returns, the check valve closes, and the water is forced into the feed-pipe to the boiler.

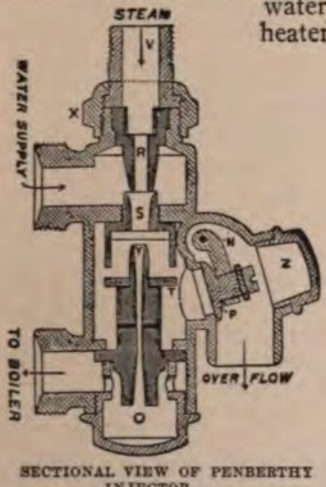


SECTIONAL VIEW OF SWING CHECK VALVE.

There are usually two check valves between the pump cylinder and the boiler, both swinging away from the pump or toward the boiler. In order that the water may flow steadily into the boiler there is an air chamber, which may be partly filled with water at each stroke of the plunger. As the water comes in, the air must be compressed, and as it expands it forces the water through the feed pipe into the boiler in a steady stream. There is one check valve between the pump cylinder and the air chamber, to prevent the water from coming back into the cylinder, and another between the air chamber and the boiler, to prevent the steam pressure forcing itself or the water from the boiler or water heater back into the air chamber.



SECTIONAL VIEW OF CASE HEATER.



SECTIONAL VIEW OF PENBERTHY INJECTOR.

U. S. AUTOMATIC INJECTOR. (American Injector Co.)

All three of these check valves must work easily and fit tight if the pump is to be serviceable. They usually close with rubber facings which in time will get worn, and dirt is liable to work into the hinge and otherwise prevent tight and easy closing. They can always be opened for inspection, and new ones can be put in when the old are too much worn.

Only cold water can be pumped successfully, as steam from hot water will expand, and so prevent a vacuum being formed. Thus no suction will take place to draw the water from the supply source.

There should always be a globe valve or cock in the feed pipe near the boiler to make it possible to cut out the check valves when the boiler is under pressure. *It is never to be closed except* when required for this purpose.

AUTOMATIC INJECTOR.

Before passing into the boiler the water from the pump goes through the *heater*. This is a small cylinder, with a coil of pipe inside. The feed pipe from the pump is connected with one end of this inner coil of pipe, while the other end of the coil leads into the boiler itself. The exhaust steam from the engine cylinder is admitted into the cylinder and passes around the coil of pipe, afterwards coming out of the smoke stack to help increase the draft. As the feed water passes through this heater it becomes heated nearly to boiling before it enters the boiler, and has no tendency to cool the boiler off. Heating the feed water results in an economy of about 10 per cent.

The Injector is another means of forcing water from a supply tank or well into the boiler, and at the same time heating it, by use of steam from the boiler. It is a necessity when a cross-head pump is used, since such a pump will not work when the engine is shut down. It is useful in any case to heat the water before it goes into the boiler when the engine is not working and there is no exhaust steam for the heater.

There are various types of injectors, but they all work on practically the same principle. The steam from the boiler is led through a tapering nozzle to a small chamber into which there is an opening from a water supply pipe. This steam nozzle throws out its spray with great force and creates a partial vacuum in the chamber, causing the water to flow in. As the pressure of the steam has been reduced when it passes into the injector, it cannot, of course, force its way back into the boiler at first, and finds an outlet at the overflow. When the water comes in, however, the steam jet strikes the water and is condensed by it. At the same time it carries the water and the condensed steam along toward the boiler with such force that the back pressure of the boiler is overcome and a stream of heated water is passed into it. In order that the injector may work, its parts must be nicely adjusted, and with varying steam pressures it takes some ingenuity to get it started. Usually the full steam pressure is turned on and the cock admitting the water supply is opened a varying amount according to the pressure.

First the valve between the check valve and the boiler should be opened, so that the feed water may enter freely; then open wide the valve next the steam dome, and any other valve between the steam supply pipe and the injector; lastly open the water supply valve. If water appears at the overflow, close the supply valve and open it again, giving it just the proper amount of turn. The injector is regulated by the amount of water admitted.

PLAIN WHISTLE.

In setting up an injector of any type, the following rules should be observed:

All connecting pipes as straight and short as possible.

The internal diameter of all connecting pipes should be the same or greater than the diameter of the hole in the corresponding part of the injector.

When there is dirt or particles of wood or other material in the source of water supply, the end of the water supply pipe should be provided with a strainer. Indeed, invariably a strainer should be used. The holes in this strainer must be as small as the smallest opening in the delivery tube, and the total area of the openings in the strainer must be much greater than the area of the water supply (cross-section).

The steam should be taken from the highest part of the dome, to avoid carrying any water from the boiler over with it. Wet steam cuts and grooves the steam nozzle. The steam should not be taken from the pipe leading to the engine unless the pipe is quite large.

Before using new injectors, after they are fitted to the boiler it is advisable to disconnect them and clean them out well by letting steam blow through them or forcing water through. This will prevent lead or loose scale getting into the injector when in use.

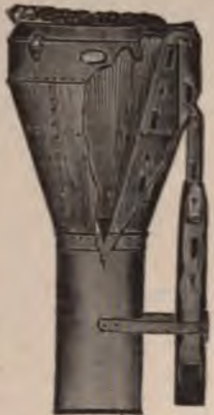
Set the injector as low as possible, as it works best with smallest possible lift.

Ejectors and jet pumps are used for lifting and forcing water by steam pressure, and are employed in filling tanks, etc.

BLAST AND BLOW-OFF DEVICES.

In traction engines there is small pipe with a valve, leading into the smoke stack from the boiler. When the valve is opened, the steam allowed to blow off into the smoke stack will create a vacuum and so increase the draft. Blast or blow pipes are used only in starting the fire, and are of little value before the steam pressure reaches 15 pounds or so.

The exhaust nozzle from the engine cylinder also leads into the smoke stack, and when the engine is running the exhaust steam is sufficient to keep up the draft without using the blower.


DIAMOND SPARK ARRESTER.

Blow-off cocks are used for blowing sediment out of the bottom of a boiler, or blowing scum off the top of the water to prevent foaming. A boiler should never be blown out at high pressure, as there is great danger of injuring it. Better let the boiler cool off somewhat before blowing off.

SPARK ARRESTER.

Traction engines are supplied as a usual thing with spark arresters if they burn wood or straw. Coal sparks are heavy and have little life, and with some engines no spark arrester is needed. But there is great danger of setting a fire if an engine is run with wood or straw without the spark arrester.

Spark arresters are of different types. The most usual form is a large screen dome placed over the top of the stack. This screen must be kept well cleaned by brushing, or the draft of the engine will be impaired by it.

In another form of spark arrester, the smoke is made to pass through water, which effectually kills every possible spark.

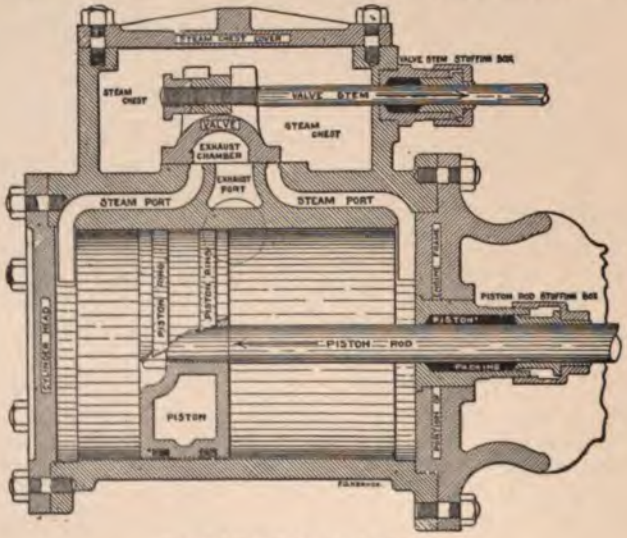
The Diamond Spark Arrester does not interfere with the draft and is so constructed that all sparks are carried by a counter current through a tube into a pail where water is kept. The inverted cone, as shown in cut, is made of steel wire cloth, which permits smoke and gas to escape, but no sparks. There is no possible chance to set fire to anything by sparks. It is adapted to any steam engine that exhausts into the smoke stack.

CHAPTER III.

THE SIMPLE ENGINE.

The engine is the part of a power plant which converts steam pressure into power in such form that it can do work. Properly speaking, the engine has nothing to do with generating steam. That is done exclusively in the boiler, which has already been described.

The steam engine was invented by James Watt, in England, between 1765 and 1790, and he understood all the essential parts of the engine as now built. It was improved, however, by Seguin, Ericsson, Stephenson, Fulton, and many others.



VIEW OF SIMPLE CYLINDER.
(J. I. Case Threshing Machine Co.)

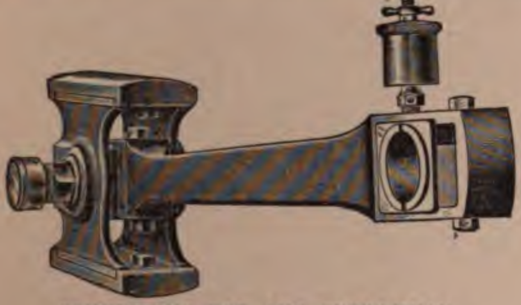
Let us first consider:

THE STEAM CYLINDER, ITS PARTS AND CONNECTIONS.

The cylinder proper is constructed of a single piece of cast iron bored out smooth.

The *cylinder heads* are the flat discs or caps bolted to the ends of the cylinder itself. Sometimes one cylinder head is cast in the same piece with the engine frame.

The *piston* is a circular disc working back and forth in the cylinder. It is usually a hollow casting, and to make it fit the cylinder steam tight, it is supplied on its circumference with *piston rings.* These are made of slightly larger diameter than the piston, and serve as springs against the sides of the cylinder. The *follower plate* and bolts cover the piston rings on the piston head and hold them in place.



CONNECTING ROD AND CROSS-HEAD.
(J. I. Case Threshing Machine Co.)

The *piston rod* is of wrought iron or steel, and is fitted firmly and rigidly into the piston at one end. It runs from the piston through one head of the cylinder, passing through a steam-tight "stuffing box." One end of the piston rod is attached to the cross-head.

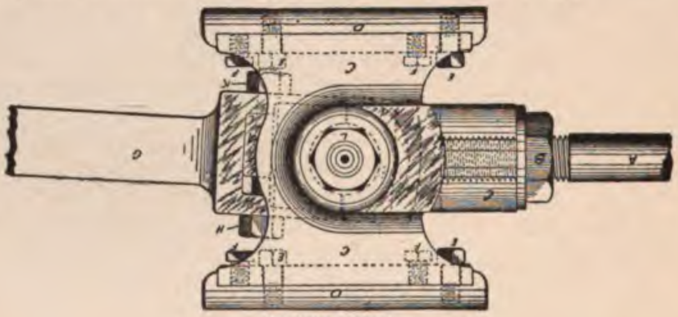
The *cross-head* works between *guides*, and has *shoes* above and below. It is practically a joint, necessary in converting straight back and forth motion into rotary. The cross-head itself works straight back and forth, just as the piston does, which is fastened firmly to one end. At the other end is attached the *connecting rod,* which works on a bearing in the cross-head, called the *wrist pin*, or cross-head pin.

The *connecting rod* is wrought iron or steel, working at one end on the bearing known as the wrist pin, and on the other on a bearing called the *crank pin*.

The *crank* is a short lever which transmits the power from the connecting rod to the *crank shaft*. It may also be a disc, called the *crank disc*.

Let us now return to the steam cylinder itself.

The steam leaves the boiler through a pipe leading from the top of the steam dome, and is let on or cut off by the *throttle* valve, which is usually opened and closed by some sort of lever handle. It passes on to the *Steam-chest*, usually a part of the same casting as the cylinder. It has a cover called the *steam-chest cover*, which is securely bolted in place.



CROSS-HEAD.
(J. I. Case Threshing Machine Co.)

The *steam valve*, usually spoken of simply as the *valve*, serves to admit the steam alternately to each end of the cylinder in such a manner that it works the piston back and forth.

There are many kinds of valves, the simplest (shown in the diagram) being the D-valve. It slides back and forth on the bottom of the steam-chest, which is called the *valve seat*, and alternately opens and closes the two *steam ports*, which are long, narrow passages through which the steam enters the cylinder, first through one port to one end, then through the other port to the other end. The exhaust steam also passes out at these same ports.

The *exhaust chamber* in the type of engine now under consideration is an opening on the lower side of the valve, and is always open into the *exhaust port,* which connects with the exhaust pipe, which finally discharges itself through the *exhaust nozzle* into the smoke stack of a locomotive or traction engine, or in other types of engines, into the *condenser.*

The valve is worked by the *valve stem,* which works through the valve stem *stuffing box.*

Of course the piston does not work quite the full length of the cylinder, else it would pound against the cylinder heads.

The *clearance* is the distance between the cylinder head at either end and the piston when the piston has reached the limit of its stroke in that direction.

In most engines the valve is so set that it opens a trifle just before the piston reaches the limit of its movement in either direction, thus letting some steam in before the piston is ready to move back. This opening, which usually amounts to 1-32 to 3-16 of an inch, is called the *lead.* The steam thus let in before the piston reaches the limit of its stroke forms *cushion,* and helps the piston to reverse its motion without any jar, in an easy and silent manner. Of course the cushion must be as slight as possible and serve its purpose, else it will tend to stop the engine, and result in loss of energy. Some engines have no lead.

Setting a valve is adjusting it on its seat so that the lead will be equal at both ends and sufficient for the needs of the engine. By shortening the movement of the valve back and forth, the lead can be increased or diminished. This is usually effected by changing the eccentric or valve gear.

The *lap* of a slide valve is the distance it extends over the edges of the ports when it is at the middle of its travel.

Lap on the steam side is called outside lap; lap on the exhaust side is called inside lap. The object of lap is to secure the benefit of working steam expansively. Having lap, the valve closes one steam port before the other is opened, and before the piston has reached the end of its stroke; also of course before the exhaust is opened. Thus for a short time the steam that has been let into the cylinder to drive the piston is shut up with neither inlet nor outlet, and it drives the piston by its own expansive force. When it passes out at the exhaust it has a considerably reduced pressure, and less of its force is wasted.

Let us now consider the

VALVE GEAR.

The mechanism by which the valve is opened and closed is somewhat complicated, as various things are accomplished by it besides simply opening and closing the valve. If an engine has a *reverse lever*, it works through the valve gear; and the *governor* which regulates the speed of the engine may also operate through the valve gear. It is therefore very important.

The simplest valve gear depends for its action on a fixed eccentric.

An *eccentric* consists of a central disc called the *sheave,* keyed to the main shaft at a point to one side of its true center, and a grooved ring or *strap* surrounding it and sliding loosely around it. The strap is usually made of brass or some anti-friction metal. It is in two parts, which are bolted together so that they can be tightened up as the strap wears.

The *eccentric rod* is either bolted to the strap or forms a single piece with it, and this rod transmits its motion to the valve.

It will be seen, therefore, that the eccentric is nothing more than a sort of disc crank, which, however, does not need to be attached to the end of a shaft in the manner of an ordinary crank.

The distance between the center of the eccentric sheave and the center of the shaft is called the *throw* of the eccentric or the *eccentricity.*

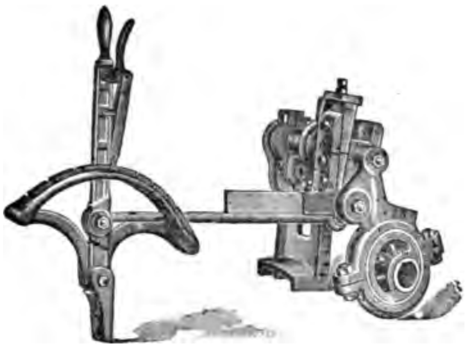
The eccentric usually conveys its force through a connecting rod to the valve stem, which moves the valve.

The first modification of the simple eccentric valve gear is

THE REVERSING GEAR.

It is very desirable to control the movement of the steam valve, so that if desired the engine may be run in the opposite direction; or the steam force may be brought to bear to stop the engine quickly; or the travel of the valve regulated so that it will let into the cylinder only as much steam as is needed to run the engine when the load is light and the steam pressure in the boiler high.

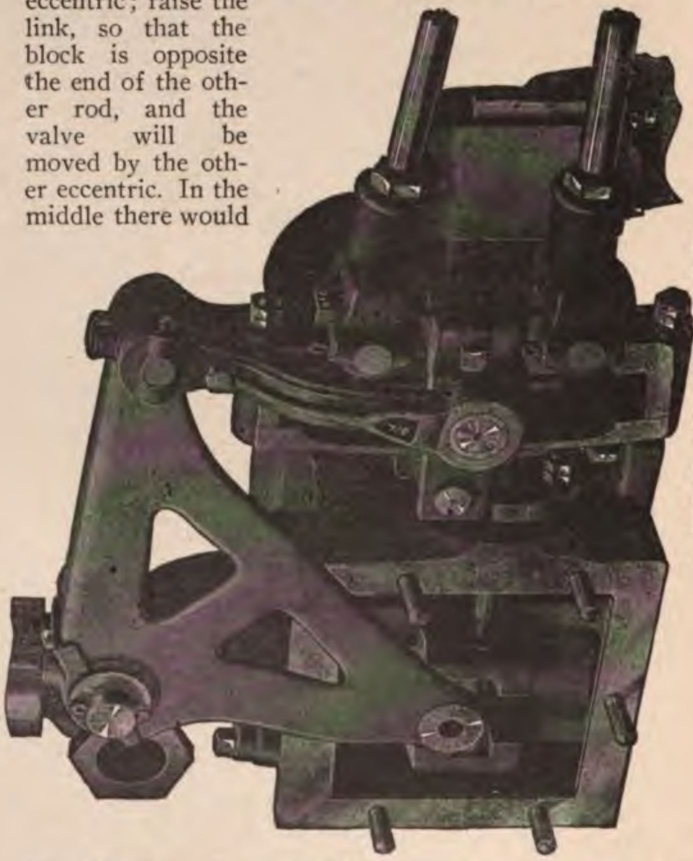
There is a great variety of reversing gears; but we will consider one of the commonest and simplest first.



HUBER SINGLE ECCENTRIC REVERSE.

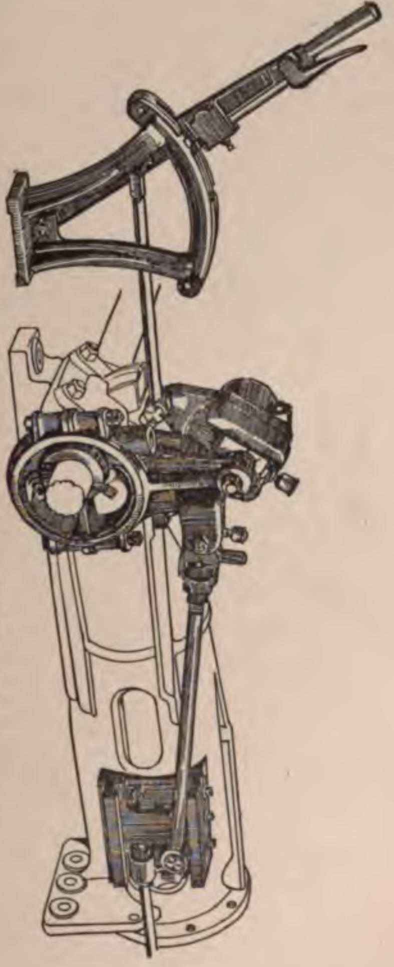
If the eccentric sheave could be slipped around on the shaft to a position opposite to that in which it was keyed to shaft in its ordinary motion, the motion of the valve would be reversed, and it would let steam in front of the advancing end of the piston, which would check its movement, and start it in the opposite direction.

The *link gear,* invented by Stephenson, accomplishes this in a natural and easy manner. There are two eccentrics placed just opposite to each other on the crank shaft, their connecting rods terminating in what is called a *link,* through which motion is communicated to the valve stem. The link is a curved slide, one eccentric being connected to one end, the other eccentric to the other end, and the *link-block,* through which motion is conveyed to the valve, slides freely from one end to the other. Lower the link so that the block is opposite the end of the first rod, and the valve will be moved by the corresponding eccentric; raise the link, so that the block is opposite the end of the other rod, and the valve will be moved by the other eccentric. In the middle there would be a dead center, and if the block stopped here, the valve would not move at all. At any intermediate point, the travel of the valve would be correspondingly shortened.



VALVE AND LINK REVERSE.

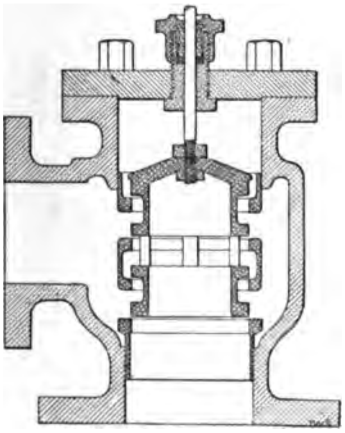
Such is he theoretical effect of a perfect link; but the dead center is not absolute, and the motion of the link is varied by the point at which the rod is attached which lifts and lowers it, and also by the length of this rod. In full gear the block is not allowed to come quite to the end of the link, and this surplus distance is called the *clearance*. The *radius* of a link is the distance from the center of the driving shaft to the center of the link, and the curve of the link is that of a circle with that radius. The length of the radius may vary considerably, but the point of suspension is important. If a link is suspended by its center, it will certainly cut off steam sooner in the front stroke than in the back. Usually it is suspended from that point which is most used in running the engine.



THE WOOLF REVERSE VALVE GEAR.

The *Woolf reversing gear* employs but one eccentric, to the strap of which is cast an arm having a block pivoted at its end. This block slides in a pivoted guide, the angle of which is controlled by the reverse lever. To the eccentric arm is attached the eccentric rod, which transmits the motion to the valve rod through a rocker arm on simple engines and through a slide, as shown in cut, on compound engines.

The Meyer valve gear does not actually reverse an engine, but controls the admission of steam by means of an additional valve riding on the back of the main valve and controlling the cut-off. The main valve is like an ordinary D-valve, except that the steam is not admitted around the ends, but through ports running through the valve, these ports being partially opened or closed by the motion of the riding valve, which is controlled by a separate eccentric. If this riding valve is connected with a governor, it will regulate the speed of an engine; and by the addition of a link the gear may be made reversible. The chief objection to it is the excessive friction of the valves on their seats.



SECTIONAL VIEW SHOWING VALVE OF WATERS GOVERNOR.

GOVERNORS.

A governor is a mechanism by which the supply of steam to the cylinder is regulated by revolving balls, or the like, which runs faster or slower as the speed of the engine increases or diminishes. Thus the speed of an engine is regulated to varying loads and conditions.

The simplest type of governor, and the one commonly used on traction engines, is that which is only a modification of the one invented by Watt. Two balls revolve around a spindle in such a way as to rise when the speed of the engine is high, and fall when it is low, and in rising and falling they open and close a valve similar to the throttle valve. The amount that the governor valve is opened or closed by the rise and fall of the governor balls is usually regulated by a thumb screw at the top or side, or by what is called a handle nut, which is usually held firm by a check nut directly over it, which should be screwed firm against the handle nut. Motion is conveyed to the governor balls by a belt and a band wheel working on a mechanism of metred cogs.

There is considerable friction about a governor of this type and much energy is wasted in keeping it going. The valve stem or spindle passes through a steam-tight stuffing box, where it is liable to stick if the packing is too tight; and if this stuffing box leaks steam, there will be immediate loss of power.

PICKERING HORIZONTAL GOVERNOR.

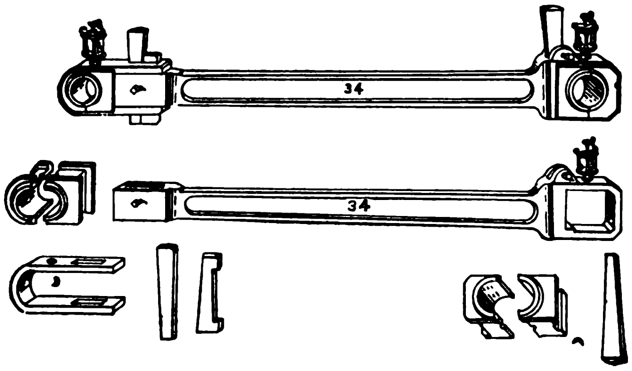
Such a governor as has just been described is called a throttle valve governor. On high grade engines the difficulties inherent in this type of governor are overcome by making the governor control, not a valve in the steam supply pipe, but the admission of steam to the steam cylinder through the steam valve and its gear. Such engines are described as having an "automatic cut-off." Sometimes the governor is attached to the link, sometimes to a separate valve, as in the Meyer gear already described. Usually the governor is attached to the fly-wheel, and consequently governors of this type are called fly-wheel governors. An automatic cut-off governor is from 15 per cent to 20 per cent more effective than a throttle valve governor.

CRANK, SHAFT AND JOURNALS.

We have already seen how the piston conveys its power through the piston rod, the cross-head, and the connecting rod, to the crank pin and crank, and hence to the shaft.

The key, gib, and strap are the effective means by which the connecting rod is attached, first to the wrist pin in the cross-head, and secondly to the crank pin on the crank.

The *strap* is usually made of two or three pieces of wrought iron or steel bolted together so as to hold the *brasses*, which are in two parts and loosely surround the pin. The brasses do not quite meet, and as they wear may be tightened up. This is effected by the *gib*, back of which is the *key*, which is commonly a wedge which may be driven in, or a screw, which presses on the back of the gib, which in turn forces together the brasses; and thus the length of the piston gear is kept uniform in spite of the wear, becoming neither shorter nor longer. When the brasses are so worn that they have been forced together, they must be taken out and filed equally on all four of the meeting ends, and shims, or thin pieces of sheet iron or the like placed back of them to equalize the wear, and prevent the piston gear from being shortened or otherwise altered.



CONNECTING ROD AND BOXES.
(A. W. Stevens Co.)

The *crank* is a simple lever attached to the shaft by which the shaft is rotated. There are two types of crank in common use, the side crank, which works by what is virtually a bend in the shaft. There is also what is called the disc crank, a variation of the side crank, in which the power is applied to the circumference of a disc instead of to the end of a lever arm.

The *boss* of a crank is that part which surrounds the shaft and butts against the main bearing, and is usually about twice the diameter of the crank shaft journal. The *web* of the crank is the portion between the shaft and the pin.

To secure noiseless running, the crank pin should be turned with great exactness, and should be set exactly parallel with the direction of the shaft. When the pressure on the pin or any bearing is over 800 pounds per square inch, oil is no longer able to lubricate it properly. Hence the bearing surface should always be large enough to prevent a greater pressure than 800 pounds to the square inch. To secure the proper proportions the crank pin should have a diameter of one-fourth the bore of the cylinder, and its length should be one-third that of the cylinder.

The *shaft* is made of wrought iron or steel, and must not only be able to withstand the twisting motion of the crank, but the bending force of the engine stroke. To prevent bending, the shaft should have a bearing as near the crank as possible.

The *journals* are those portions of the shaft which work in bearings. The main bearings are also called *pedestals, pillow blocks,* and *journal boxes.* They usually consist of boxes made of brass or some other anti-friction material carried in iron pedestals. The pillow blocks are usually adjustable.

THE FLY-WHEEL.

This is a heavy wheel attached to the shaft. Its object is to regulate the variable action of the piston, and to make the motion uniform even when the load is variable. By its inertia it stores energy, which would keep the engine running for some time after the piston ceased to apply any force or power.

LUBRICATORS.

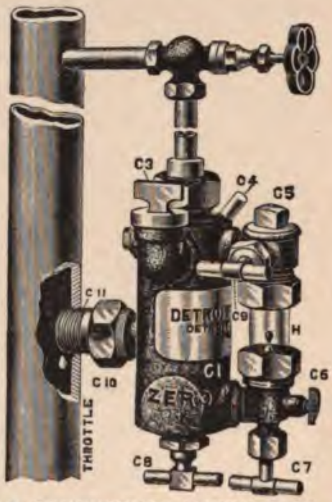
All bearings must be steadily and effectively lubricated, in order to remove friction as far as possible, or the working power of the engine will be greatly reduced. Besides, without complete and effective lubrication, the bearings will "cut," or wear in irregular grooves, etc., quickly ruining the engine.

Bearings are lubricated through automatic lubricator cups, which hold oil or grease and discharge it uniformly upon the bearing through a suitable hole.

A sight feed ordinary cup permits the drops of oil to be seen as they pass downward through a glass tube, and also the engineer may see how much oil there is in the cup. Such a cup is suitable for all parts of an engine except the crank pin, cross-head, and, of course, the cylinder.

DESCRIPTION.

C 1—Body or Oil Reservoir.
C 3—Filler Plug.
C 4—Water Valve.
C 5—Plug for Inserting Sight-Feed Glass.
C 6—Sight-Feed Drain Stem.
C 7—Regulating Valve.
C 8—Drain Valve.
C 9—Steam Valve.
C 10—Union Nut.
C 11—Tail Piece.
H—Sight-Feed Glass.



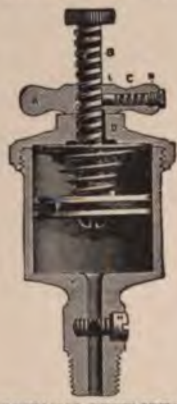
THE "DETROIT" ZERO DOUBLE CONNECTION LUBRICATOR.

The crank pin oiler is an oil cup so arranged as to force oil into the bearing only when the engine is working, and more rapidly as the engine works more rapidly. In one form, which uses liquid oil, the oil stands below a disc, from which is the opening through the shank to the bearing. As the engine speeds up, the centrifugal force tends to force the oil to the top of the cup and so on to the bearing, and the higher the speed the greater the amount of oil thrown into the crank pin.

Hard oil or grease has of late been coming into extensive use. It is placed in a compression cup, at the top of which a disc is pressed down by a spring, and also by some kind of a screw. From time to time the screw is tightened up by hand, and the spring automatically forces down the grease.

The Cylinder Lubricator is constructed on a different principle, and uses an entirely different kind of oil, called "cylinder oil." A sight-feed automatic oiler is so arranged that the oil passes through water drop by drop, so that each drop can be seen behind glass before it passes into the steam pipe leading from the boiler to the cylinder. The oil mingles with the steam and passes into the steam chest, and thence into the cylinder, lubricating the valve and piston.

GLASS OIL CUP.



SECTIONAL VIEW IDEAL GREASE CUP.

The discharge of the oil may not only be watched, but regulated, and some judgment is necessary to make sure that enough oil is passing into the cylinder to prevent it from cutting.

The oil is forced into the steam by the weight of the column of water, since the steam pressure is the same at both ends. There is a small cock by which this water of condensation may be drained off when the engine is shut down in cold weather. Oilers are also injured by straining from heating caused by the steam acting on cold oil when all the cocks are closed. There is a relief cock to prevent this strain, and it should be slightly opened, except when oiler is being filled.

ACORN OIL PUMP.

There are a number of different types of oilers, with their cocks arranged in different ways; but the manufacturer always gives diagrams and instructions fully explaining the working of the oiler. Oil pumps serving the same purpose are now often used.

DIFFERENTIAL GEAR.

The gearing by which the traction wheels of a traction engine are made to drive the engine is an important item. Of course, it is desirable to apply the power of the engine to both traction wheels; yet if both hind wheels were geared stiff, the engine could not turn from a straight line, since in turning one wheel must move faster than the other. The differential or compensating gear is a device to leave both wheels free to move one ahead of the other if occasion requires. The principle is much the same as in case of a rachet on a geared wheel, if power were applied to the ratchet to make the wheel turn; if for any reason the wheel had a tendency of its own to turn faster than the ratchet forced it, it would be free to do so. When corners are turned the power is applied to one wheel only, and the other wheel is permitted to move faster or slower than the wheel to which the gearing applies the power.

There are several forms of differential gears, differing largely as to combination of spur or bevel cogs. One of the best known uses four little beveled pinions, which are placed in the main driving wheel as shown in the cut. Beveled cogs work into these on either side of the main wheel. If one traction wheel moves faster than the other these pinions move around and adjust the gears on either side.

FRICTION CLUTCH.

The power of an engine is usually applied to the traction wheel by a friction clutch working on the inside of

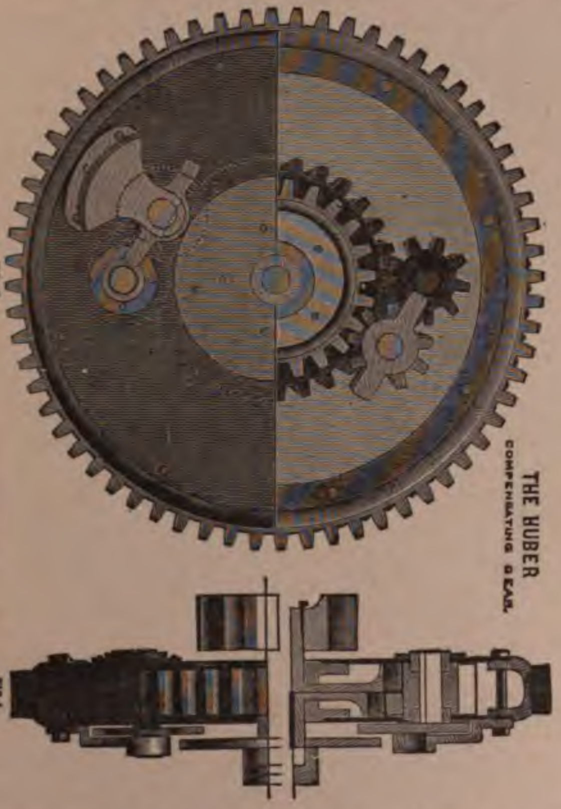


FIG. 2

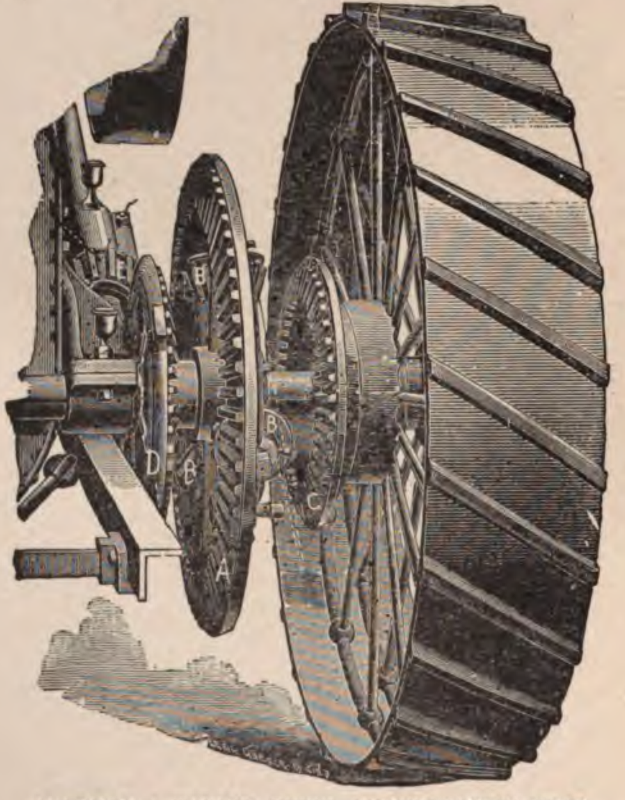
FIG. 1

THE HUBER SPUR COMPENSATING GEAR.

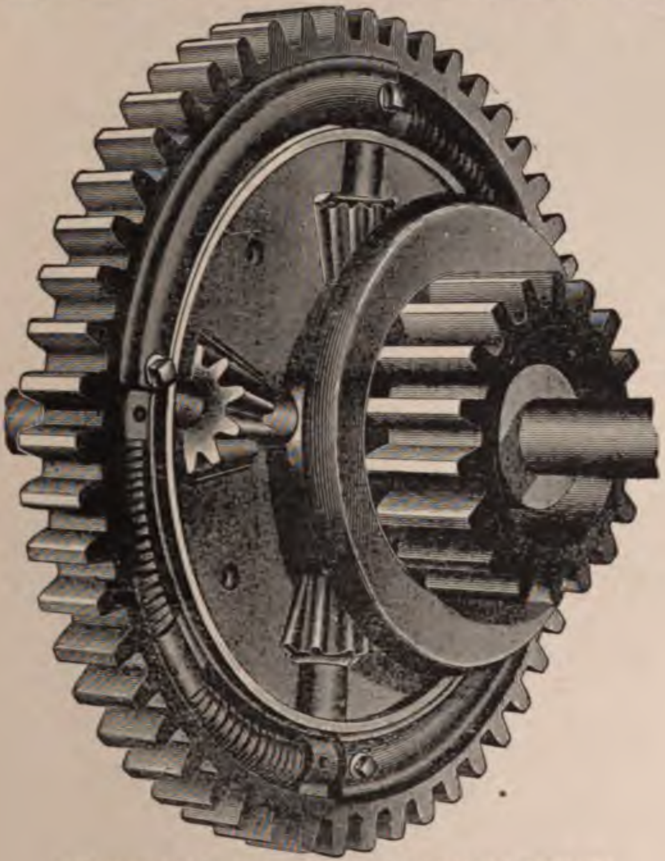
the fly-wheel. (See plan of Frick Engine.) The traction wheels are the two large, broad-rimmed hind wheels, and are provided with projections to give them a firm footing on the road. Traction engines are also provided with mud shoes and wheel cleaning devices for mud and snow.

THE FUSIBLE PLUG.

The fusible plug is a simple screw plug, the center of which is bored out and subsequently filled with some other metal that will melt at a lower temperature than steel or iron. This plug is placed in the crown sheet of a locomotive boiler as a precaution for



AULTMAN & TAYLOR BEVEL COMPENSATING GEAR safety. Should the crown sheet become free of water when the fire is very hot, the soft metal in the fusible plug would melt and run out, and the overheated steam would escape into the firebox, putting out the fire and giving the boiler relief so that an explosion would be avoided. In some states a fusible plug is required by



DIFFERENTIAL GEAR, SHOWING CUSHION SPRINGS AND BEVEL PINION.

law, and one is found in nearly every boiler which has a crown sheet. Return flue boilers and others which do not have crown sheets (as for example the vertical) do not have fusible plugs. To be of value a fusible plug should be renewed or changed once a month.

STUFFING BOXES.

Any arrangement to make a steam-tight joint about a moving rod, such as a piston rod or steam valve rod, would be called a stuffing box. Usually the stuffing box gives free play to a piston rod or valve rod, without allowing any steam to escape. A stuffing box is also used on a pump piston sometimes, or a compressed air piston. In all these cases it consists of an annular space around the moving rod which can be partly filled by some pliable elastic material such as hemp, cotton, rubber, or the like; and this filling is held in place and made tighter or looser by what is called a gland, which is forced into the partly filled box by screwing up a cap on the outside of the cylinder. Stuffing boxes must be repacked occasionally, since the packing material will get hard and dead, and will either leak steam or cut the rod.

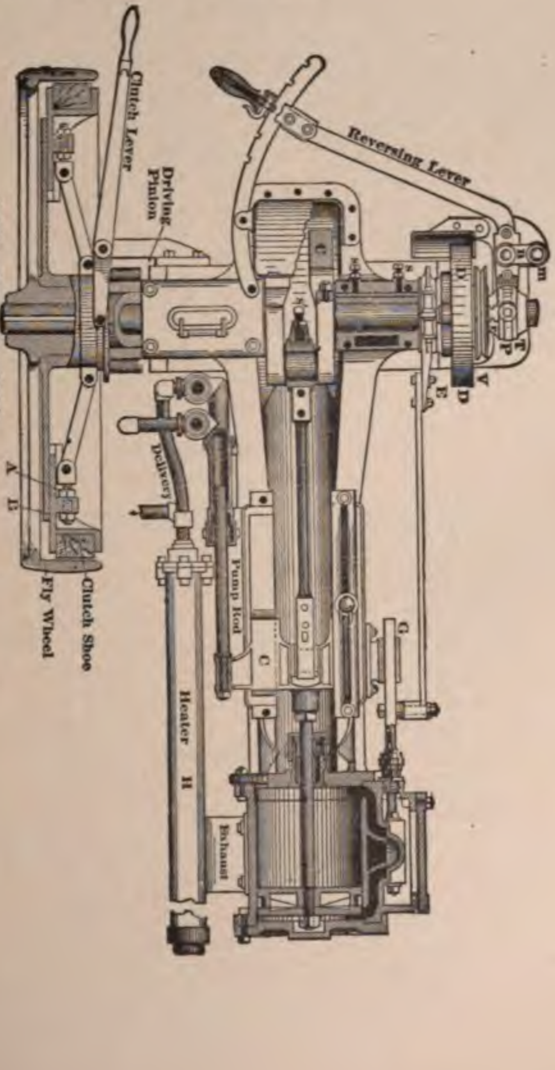
CYLINDER COCKS.

These cocks are for the purpose of drawing the water formed by condensation of steam out of the cylinder. They should be opened whenever the engine is stopped or started, and should be left open when the engine is shut down, especially in cold weather to prevent freezing of water and consequent damage. Attention to these cocks is very important.

These are small cocks arranged about the pump and at other places for the purpose of testing the inside action. By them it is possible to see if the pump is working properly, etc.

STEAM INDICATOR.

The steam indicator is an instrument that can be attached to either end of a steam cylinder, and will indicate the character of the steam pressure during the entire stroke of the piston. It shows clearly whether the lead is right, how much cushion there is, etc. It is very important in studying the economical use and distribution of steam, expansive force of steam, etc.



THE FRICK COMPANY TRACTION ENGINE.

Plan view of "Eclipse" Traction Engine, showing arrangement of **Patent Reverse Gear and** Friction Clutch for Driving Pinion.

LIST OF ATTACHMENTS FOR TRACTION ENGINE AND BOILER.

The following list of brasses, etc., which are packed with the Case traction engine will be useful for reference in connection with any similar traction engine and boiler. The young engineer should rapidly run over every new engine and locate each of these parts, which will be differently placed on different engines:

1 Steam Gauge with siphon.
1 Safety Valve.
1 Large Lubricator
1 Small Lubricator for Pump.
1 Glass Water Gauge complete with glass and rods.
2 Gauge Cocks.
1 Whistle.
1 Injector Complete.
1 Globe Valve for Blow-off.
1 Compression Grease Cup for Cross Head.
1 Grease Cup for Crank Pin.
1 Oiler for Reverse Block.
1 Glass Oiler for Guides.
1 Small Oiler for Eccentric Rod.
1 Cylinder Cock (1 is left in place.
2 Stop Cocks to drain Heater.
1 Stop Cock for Hose Coupling on Pump.
1 Bibb Nose Cock for Pump.
1 Pet Cock for Throttle.
2 Pet Cocks for Steam Cylinder of Pump.
1 Pet Cock for Water Cylinder of Pump.
1 Pet Cock for Feed Pipe from Pump.
1 Pet Cock for Feed Pipe from Injector.
1 Governor Belt.
1 Flue Cleaner.
15 ft. lin. Suction Hose.
5 ft. Sprinkling Hose.
1 Strainer for Suction Hose.
1 Strainer for Funnel.
4 ft. 6 in. of in. Hose for Injector.
5 ft. 6 in of in. Hose for Pump.
2 Nipples ¾x2½ in. for Hose.
2 ¾ in. Hose Clamps.
2 ½ in. Hose Strainers.

TEST QUESTIONS ON BOILER AND ENGINE

Q. How is the modern stationary fire-flue boiler arranged?

Q. How does the locomotive type of boiler differ?

Q. What is a return flue boiler?

Q. What is a water-tube boiler and how does it differ from a fire-flue tubular boiler?

Q. What is a vertical boiler and what are its advantages?

Q. What is the shell?

Q. What are the boiler heads?

Q. What are the tube sheets?

Q. What is the firebox?

Q. What is the water leg?

Q. What is the crown-sheet?

Q. Where is the smoke-box located?

Q. What is the steam dome intended for?

Q. What is the mud-drum for?

Q. What are man-holes and hand-holes for?

Q. What is a boiler jacket?

Q. What is a steam jacket?

Q. Where is the ash-pit?

Q. What are dead-plates?

Q. How is grate surface measured?

Q. What is forced draft?

Q. How is heating surface measured?

Q. What is steam space?

Q. What is water space?

Q. What is a diaphragm plate?

Q. What is the first duty of an engineer in taking charge of a new boiler?

Q. What are the water gauge and try cocks for, and how are they placed?

Q. What is the steam gauge and how may it be tested?

Q. What is a safety valve? Should it be touched by the engineer? How may he test it with the steam gauge?

Q. How is a boiler first filled with water?

Q. How is it filled when under pressure?

Q. What is an independent pump? What is a crosshead pump?

Q. What is a check valve, and what is its use, and where located?

Q. What is a heater and how does it work?

Q. What is an injector, and what is the principle of its operation?

Q. Where are the blow-off cocks located? How should they be used?

Q. In what cases should spark arrester be used?

Q. Who invented the steam engine, and when?

Q. What are the essential parts of a steam engine?

Q. What is the cylinder, and how is it used?

Q. What is the piston, and how does it work? The piston-rings?

Q. What is the piston rod and how must it be fastened?

Q. What is the crosshead, and how does it move? What are guides or ways? Shoes?

Q. What is the connecting rod? Wrist pin? Crank pin?

Q. What is the crank? Crank shaft?

Q. Where is the throttle valve located, and what does opening and closing it do?

Q. What is the steam chest for, and where is it placed?

Q. What is a steam valve? Valve seats? Ports?

Q. What is the exhaust? Exhaust chamber? Exhaust port? Exhaust nozzle? What is a condenser?

Q. How is the valve worked, and what duties does it perform, and how?

Q. What is clearance?

Q. What is lead?

Q. What is cushion?

Q. How would you set a valve? What is lap?

Q. How is a steam valve moved back and forth in its seat?

Q. How may an engine be reversed?

Q. What is a governor, and how does it work?

Q. What is an eccentric? Eccentric sheave? Strap? Rod?

Q. What is the throw of an eccentric?

Q. How does the link reversing gear work?

Q. How does the Woolf reverse gear work?

Q. How does the Meyer valve gear work? Will it reverse an engine?

Q. What are the chief difficulties in the working of a governor?

Q. What are key, gib, and strap? Brasses?

Q. What is the boss of a crank? Web?

Q. How may noiseless running of a crank be secured?

Q What are journals? Pedestals? Pillow blocks? Journal boxes?

Q. What is the object in having a fly wheel?

Q. What different kinds of lubricators are there? Where may hard oil or grease be used? Is the oil used for lubricating the cylinder the same as that used for rest of engine?

Q. How does a cylinder lubricator work?

Q. What is differential gear, and what is it for?

Q. What is the use of a fusible plug, and how is it arranged?

Q. What are stuffing-boxes, and how are they constructed?

Q. What are cylinder cocks, and what are they used for?

Q. What are pet cocks?

Q. What is a steam indicator?

CHAPTER IV.

HOW TO MANAGE A TRACTION ENGINE BOILER.

We will suppose that the young engineer fully understands all parts of the boiler and engine, as explained in the preceding chapters. It is well to run over the questions several times, to make sure that every point has been fully covered and is well understood.

We will suppose that you have an engine in good running order. If you have a new engine and it starts off nice and easy (the lone engine without load) with twenty pounds steam pressure in the boiler, you may make up your mind that you have a good engine to handle and one that will give but little trouble. But if it requires fifty or sixty pounds to start it, you want to keep your eyes open, for something is tight. But don't begin taking the engine to pieces, for you might get more pieces than you know what to do with. Oil every bearing fully, and then start your engine and let it run for a while. Then notice whether you find anything getting warm. If you do, stop and loosen up a very little and start again. If the heating still continues, loosen again as before. But remember, loosen but little at a time, for a box or journal will heat from being too loose as quickly as from being too tight, and if you have found a warm box, don't let that box take all your attention, but keep your eye on the other bearings.

In the case of a new engine, the cylinder rings may be a little tight, and so more steam pressure will be required to start the engine; but this is no fault, for in a day or two they will be working all right if kept well oiled.

In starting a new engine trouble sometimes comes from the presence of a coal cinder in some of the boxes, which has worked in during shipment. Before starting a new engine, the boxes and oil holes should therefore be thoroughly cleaned out. For this purpose the engineer should always have some cotton waste or an oiled rag ready for constant use.

A new engine should be run slowly and carefully until it is found to be in perfect running order.

If you are beginning on an old engine in good running order, the above instructions will not be needed; but it is well to take note of them.

Now if your engine is all right, you may run the pressure up to the point of blowing off which is 100 to 130 pounds, at which most safety valves are set at the factory. It is not uncommon for a new pop to stick, and as the steam runs up it is well to try it by pulling the relief lever. If on letting it go it stops the escaping steam at once, it is all right. If, however, the steam continues to escape the valve sticks in the chamber. Usually a slight tap with a wrench or hammer will stop it at once; but don't get excited if the steam continues to escape. As long as you have plenty of water in the boiler, and know that you have it, you are all right.

STARTING UP A BOILER.

Almost the only danger from explosion of a boiler is from not having sufficient water in the boiler. The boiler is filled in the first place, as has already been explained, by hand through a funnel at the filler plug, or by a force pump. The water should stand an inch and a half in the glass of the water gauge before the fire is started. It should be heated up slowly so as not to strain the boiler or connections. When the steam pressure as shown by the steam gauge is ten or fifteen pounds, the blower may be used to increase the draft.

If you let the water get above the top of the glass, you are liable to knock out a cylinder head; and if you let the water get below the bottom of the glass, you are likely to explode your boiler.

The glass gauge is not to be depended upon, however, for a number of things may happen to interfere with its working. Some one may inadvertently turn off the gauge cocks, and though the water stands at the proper height in the glass, the water in the boiler will be very different.

A properly made boiler is supplied with two to four try-cocks, one below the proper water line, and one above it. If there are more than two they will be distributed at suitable points between.

When the boiler is under pressure, turn on the lower try-cock and you should get water. You will know it because it will appear as white mist. Then try the upper try-cock, and you will get steam, which will appear blue.

NEVER FAIL TO USE THE TRY-COCKS FREQUENTLY. This is necessary not only because you never know when the glass is deceiving you; but if you fail to use them they will get stopped up with lime or mud, and when you need to use them they will not work.

In order also to keep the water gauge in proper condition, it should be frequently blown out in the following manner: Shut off the top gauge cock and open the drain cock at the bottom of the gauge. This allows the water and steam to blow through the lower cock of the water gauge, and you know that it is open. Any lime or mud that has begun to accumulate will also be carried off. After allowing the steam to escape a few seconds, shut off the lower gauge cock, and open the upper one, and allow it to blow off about the same time. Then shut the drain cock and open both gauge cocks, when you will see the water seek its level, and you can feel assured that it is reliable and in good working condition. This little operation you should perform every day you run your engine. If you do you will not *think* you have sufficient water in the boiler, but will *know*. The engineer who always *knows* he has water in the boiler will not be likely to have an explosion. Especially should you never start your fire in the morning simply because you see water in the gauge. You should *know* that there is water in the boiler.

Now if your pump and boiler are in good working condition, and you leave the globe valve in the supply pipe to the pump open, with the hose in the tank, you will probably come to your engine in the morning and find the boiler nearly full of water, and you will think some one has been tampering with the engine. The truth is, however, that as the steam condensed, a vacuum was formed, and the water flowed in on account of atmospheric pressure, just as it flows into a suction pump when the plunger rises and creates a vacuum in the pump. Check valves are arranged to prevent anything passing out of the boiler, but there is nothing to prevent water passing in.

The only other cause of an explosion, beside poor material in the manufacture of the boiler, is too high steam pressure, due to a defective safety valve or imperfect team gauge. The steam gauge is likely to get out of order in a number of ways, and so is the safety valve. To make sure that both are all right, the one should frequently be tested by the other. The lever of the safety valve should frequently be tried from time to time, to make sure the valve opens and closes easily, and whenever the safety valve blows off, the steam gauge should be noted to see if it indicates the pressure at which the safety has been set.

WHEN YOUR ENGINE IS ALL RIGHT, LET IT ALONE.

Some engineers are always loosening a nut here, tightning up a box there, adjusting this, altering that. When an engine is all right they keep at it till it is all wrong. As a result they are in trouble most of the time. When an engine is running all right, LET IT ALONE. Don't think you are not earning your salary because you are nerely sitting still and looking on. If you must be at work, keep at it with an oily rag, cleaning and polishing up. That is the way to find out if anything is really the matter. As the practised hand of the skilled engineer goes over an engine, his ears wide open for any peculiarity of sound, anything that is not as it should be will make itself decidedly apparent. On the other hand, an engineer who does not keep his engine clean and bright by constantly passing his hand over it with an oily rag, is certain to overlook something, which perhaps in the end will cost the owner a good many dollars to put right.

Says an old engineer* we know, "When I see an engineer watching his engine closely while running, I am most certain to see another commendable feature in a good engineer, and that is, when he stops his engine he will pick up a greasy rag and go over his engine carefully, wiping every working part, watching or looking carefully at every point that he touches. If a nut is working loose, he finds it; if a bearing is hot, he finds it; if any part of his engine has been cutting, he finds it. He picks up a greasy rag instead of a wrench, for the engineer that understands his business and attends to it never picks up a wrench unless he has something to do with it."

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*J. H. Maggard, author of "Rough and Tumble Engineering," to whom we are indebted for a number of valuable suggestions in this chapter.

This same engineer goes on with some more most excellent advice. Says he:

"Now, if your engine runs irregularly, that is, if it runs up to a higher speed than you want, and then runs down, you are likely to say at once, 'Oh, I know what the trouble is, it is the governor.' Well, suppose it is. What are you going to do about it? Are you going to shut down at once and go to tinkering with it? No, don't do that. Stay close to the throttle valve and watch the governor closely. Keep your eye on the governor stem, and when the engine starts off on one of its speed tilts, you will see the stem go down through the stuffing box and then stop and stick in one place until the engine slows down below its regular speed, and it then lets loose and goes up quickly and your engine lopes off again. You have now located the trouble. It is in the stuffing box around the little brass rod or governor stem. The packing has become dry and by loosening it up and applying oil you may remedy the trouble until such time as you can repack it with fresh packing. Candle wick is as good for this purpose as anything you can use.

"But if the governor does not act as I have described, and the stem seems to be perfectly free and easy in the box, and the governor still acts queerly, starting off and running fast for a few seconds and then suddenly concluding to take it easy and away goes the engine again, see if the governor belt is all right, and if it is it would be well for you to stop and see if a wheel is not loose. It might be either the little belt wheel or one of the little cog wheels. If you find these are all right, examine the spool on the crank shaft from which the governor is run, and you will probably find it loose. If the engine has been run for any length of time, you will always find the trouble in one of these places; but if it is a new one, the governor valve might work a little tight in the valve chamber, and you may have to take it out and use a little emery paper to take off the rough projections on the valve. Never use a file on this valve if you can get emery paper, and I should advise you always to have some of it with you. It will often come handy."

This is good advice in regard to any trouble you may have with an engine. Watch the affected part closely; think the matter over carefully, and see if you cannot locate the difficulty before you even stop your engine. If you find the trouble and know that you have found it, you will soon be able to correct the defect, and no time will be lost. At the same time you will not ruin your engine by trying all sorts of remedies at random in the thought that you may ultimately hit the right thing. The chances are that before you do hit the right point, you will have put half a dozen other matters wrong, and it will take half a day to get the matter right again.

As there are many different types of governors in use, it would be impossible to give exact directions for regulating that would apply to them all; but the following suggestions applying to the Waters governor (one widely used on threshing engines) will give a general idea of the method for all:

There are two little brass nuts on the top of the stem of the governor, one a thumb nut and the other a loose jam nut. To increase the speed, loosen the jam nut and then turn the thumb nut back slowly, watching the motion of the engine all the time. When the required speed has been obtained, then tighten up as snug as you can with your fingers (not using a wrench). To decrease the speed, loosen the jam nut as before, running it up a few turns, and then turn down the thumb nut till the speed meets your requirements, when the thumb nut is made fast as before. In any case, be very careful not to press down on the stem when turning the thumb nut, as this will make the engine run a little slower than will be the case when your hand has been removed.

If your engine does not start with an open throttle, look to see if the governor stem has not been screwed down tight. This is usually the case with a new engine, which has been screwed down for safety in transportation.

WATER FOR THE BOILER.

There is nothing that needs such constant watching and is likely to cause so much trouble if it is not cared for, as the supply of water. Hard well water will coat the inside of the boiler with lime and soon reduce its steaming power in a serious degree, to say nothing of stopping up pipes, cocks, etc. At the same time, rain water that is perfectly pure (theoretically) will be found to have a little acid or alkali in it that will eat through the iron or steel and do equal damage.

However, an engineer must use what water he can. He cannot have it made to order for him, but he must take it from well, from brook, or cistern, or roadside ditch, as circumstances may require. The problem for the engineer is not to get the best water, but to make the best use of whatever water he can get, always, of course, choosing the best and purest when there is such a thing as choosing.

In the first place, all supply pipes in water that is muddy or likely to have sticks, leaves, or the like in it, should be furnished with strainers. If sticks or leaves get into the valve, the expense in time and worry to get them out will be ten times the cost of a strainer.

If the water is rain water, and the boiler is a new one, it would be well to put in a little lime to give the iron a slight coating that will protect it from any acid or alkali corrosion.

If the water is hard, some compound or sal ammonia should be used. No specific directions can be given, since water is made hard by having different substances dissolved in it, and the right compound or chemical is that which is adapted to the particular substance you are to counteract. An old engineer says his advice is to use no compound at all, but to put a hatful of potatoes in the boiler every morning.

Occasionally using rain water for a day or two previous to cleaning is one of the best things in the world to remove and throw down all scale. It beats compounds at every point. It is nature's remedy for the bad effects of hard water.

The important thing, however, is to clean the boiler thoroughly and often. In no case should the lime be allowed to bake on the iron. If it gets thick, the iron or steel is sure to burn, and the lime to bake so hard it will be almost impossible to get it off. But if the boiler is cleaned often, such a thing will not happen.

Mud or sediment can be blown off by opening the valve from the mud drum or the firebox at the bottom of the boiler when the pressure is not over 15 or 20 pounds; and at this pressure much of the lime distributed about the boiler may be blown off. But this is not enough. The inside of the boiler should be scraped and thoroughly washed out with a hose and force-pump just as often as the condition of the water requires it.

In cleaning the boiler, always be careful to scrape all the lime off the top of the fusible plug.

THE PUMP.

In order to manage the pump successfully, the young engineer must understand thoroughly its construction as already described. It is also necessary to understand something of the theory of atmospheric pressure, lifting power, and forcing power.

First see that the cocks or globe valves (whichever are used) are open both between the boiler and the pump and between the pump and the water supply. The globe valve next the boiler should *never* be closed, except when examining the boiler check valve. Then open the little pet cock between the two upper horizontal check valves. Be sure that the check valves are in good order, so that water can pass only in one direction. A clear, sharp click of the check valves is certain evidence that the pump is working well. If you cannot hear the click, take a stick or pencil between your teeth at one end, put the other end on the valve, stuff your fingers in your ears, and you will hear the movement of the valve as plainly as if it were a sledge-hammer.

The small drain cock between the horizontal check valves is used to drain hot water out of the pump in starting, for a pump will never work well with hot water in it; and to drain off all water in closing down in cold weather, to prevent damage from freezing. It also assists in testing the working of the pump. In starting up it may be left open. If water flows from the drain cock, we know the pump is working all right, and then close the drain cock. If you are at any time in doubt as to whether water is going into the boiler properly, you may open this drain cock and see if cold water flows freely. If it does, everything is working as it should. If hot water appears, you may know something is wrong. Also, to test the pump, place your hand on the two check valves, and if they are cold, the pump is all right; if they are hot, something is wrong, since the heat must come from the boiler, and no hot water or steam should ever be allowed to pass from the boiler back to the pump.

A stop cock next the boiler is decidedly preferable to a globe valve, since you can tell if it is open by simply looking at it; whereas you must put your hand on a globe valve and turn it. Trouble often arises through inadvertently closing the valve or cock next the boiler, in which case, of course, no water can pass into the boiler, and the pump is likely to be ruined, since the water must get out somewhere. Some part of the pump would be sure to burst if worked against a closed boiler cock or valve.

Should the pump suddenly cease to work or stop, first see if you have any water in the tank. If there is water, stoppage may be due to air in the pump chamber, which can get in only through the stuffing-box. If this is true, tighten up the pump plunger stuffing-box nut a little. If now the pump starts off well, you have found the difficulty; but at the first opportunity you ought to repack the stuffing-box.

If the stuffing-box is all right, examine the supply suction hose. See that nothing is clogging the strainer, and ascertain whether the water is sucked in or not. If it is sucked in and then is forced out again (which you can ascertain by holding your hand lightly over the suction pipe), you may know something is the matter with the first check valve. Probably a stick or stone has gotten into it and prevents it from shutting down.

If there is no suction, examine the second check valve. If there is something under it that prevents its closing, the water will flow back into the pump chamber again as soon as the plunger is drawn back.

You can always tell whether the trouble is in the second check or in the hot water check valve by opening the little drain cock. If hot water flows from it, you may know that the hot water check valve is out of order; if only cold water flows, you may be pretty sure the hot water check is all right. If there is any reason to suspect the hot water check valve, close the stop cock or valve next the boiler before you touch the check in any way. To tamper with the hot water check while the steam pressure is upon it would be highly dangerous, for you are liable to get badly burned with escaping steam or hot water. At the same time, be very sure the stop cock or valve next the boiler is open again before you start the pump.

Another reason for check valves refusing to work besides having something under them, is that the valve may stick in the valve chamber because of a rough place in the chamber, or a little projection on the valve. Light tapping with a wrench may remedy the matter. If that does not work, try the following plan suggested by an old engineer*: "Take the valve out, bore a hole in a board about one-half inch deep, and large enough to permit the valve to be turned. Drop a little emery dust in this hole. If you haven't any emery dust, scrape some grit from a whetstone. If you have no whetstone, put some fine sand or gritty soil in the hole, put the valve on top of it, put your brace on the valve and turn it vigorously for a few minutes, and you will remove all roughness."

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*J. H Maggard.

Sometimes the burr on the valve comes from long use; but the above treatment will make it as good as new.

INJECTORS.

All injectors are greatly affected by conditions, such as the lift, the steam pressure, the temperature of the water, etc. An injector will not use hot water well, if at all. As the lift is greater, the steam pressure required to start is greater, and at the same time the highest steam pressure under which the injector will work at all is greatly decreased. The same applies to the lifting of warm water: the higher the temperature, the greater the steam pressure required to start, and the less the steam pressure which can be used as a maximum.

It is important for the sake of economy to use the right sized injector. Before buying a new injector, find out first how much water you need for your boiler, and then buy an injector of about the capacity required, though of course an injector must always have a maximum capacity in excess of what will be required.

If the feed water is cold, a good injector ought to start with 25 pounds steam pressure and work up to 150 pounds for a 2-foot lift. If the lift is eight feet, it will start at 30 pounds and work up to 130. If the water is heated to 100 degrees Fahrenheit it will start for a 2-foot lift with 26 pounds and work up to 120 pounds, or for an 8-foot lift, it will start with 33 pounds and work up to 100. These figures apply to the single tube injector. The double tube injector should work from 14 pounds to 250, and from 15 to 210 under same conditions as above. The double tube injector is not commonly used on farm engines, however.

Care should be taken that the injector is not so near the boiler as to become heated, else it will not work. If it gets too hot, it must be cooled by pouring cold water on the outside, first having covered it with a cloth to hold the water. If the injector is cool, and the steam pressure and lift are all right, and still the injector does not work, you may be sure there is some obstruction somewhere. Shut off the steam from the boiler, and run a fine wire down through the cone valve or cylinder valve, after having removed the cap or plug nut.

Starting an injector always requires some skill, and injectors differ. Some start by manipulating the steam valve; some require that the steam be turned on first, and then the water turned on in just the right amount, usually with a quick short twist of the supply valve. Often some patience is required to get just the right turn on it so that it will start.

Of course you must be sure that all joints are air-tight, else the injector will not work under any conditions.

Never use an injector where a pump can be used, as the injector is much more wasteful of steam. It is for an emergency or to throw water in a boiler when engine is not running.

No lubricator is needed on an injector.

THE HEATER.

The construction of the heater has already been explained. It has two check valves, one on the side of the pump and one on the side of the boiler, both opening toward the boiler. The exhaust steam is usually at a temperature of 215 to 220 degrees when it enters the heater chamber, and heats the water nearly or quite to boiling point as it passes through. The injector heats the water almost as hot.

The heater requires little attention, and the check valves seldom get out of order.

The pump is to be used when the engine is running, and the injector when the engine is closed down. The pump is the more economical; but when the engine is not working the exhaust steam is not sufficient to heat the water in the heater; and pumping cold water into the boiler will quickly bring down the pressure and injure the boiler.

ECONOMICAL FIRING.

The management of the fire is one of the most important things in running a steam engine. On it depend two things of the greatest consequence—success in getting up steam quickly and keeping it at a steady pressure under all conditions; and economy in the use of fuel. An engineer who understands firing in the most economical way will probably save his wages to his employer over the engineer who is indifferent or unscientific about it. Therefore the young engineer should give the subject great attention.

First, let us consider firing with coal. All expert engineers advise a "thin" fire. This means that you should have a thin bed of coals, say about four inches thick, all over the grate. There should be no holes or dead places in this, for if there are any, cold air will short-circuit into the fire flues and cool off the boiler.

The best way of firing is to spread the coal on with a small hand shovel, a very little at a time, scattering it well over the fire. Another way, recommended by some, is to have a small pile of fresh fuel at the front of the grate, pushing it back over the grate when it is well lighted. To manage this well will require some practice and skill, and for a beginner, we recommend scattering small shovelsful all over the fire. All lump coal should be broken to a uniform size. No piece larger than a man's fist should be put in a firebox.

Seldom use the poker above the fire, for nothing has such a tendency to put out a coal fire as stirring it with a poker above. And when there is a good glow all over the grate below, the poker is not needed below. When the grate becomes covered with dead ashes, they should be cautiously but fully removed, and clinkers must be lifted out with the poker from above, care being exercised to cover up the holes with live coals.

Hard coal if used should be dampened before being put on the fire.

When the fire is burning a little too briskly, close the draft but do not tamper with the fire itself. Should it become important on a sudden emergency to check the fire at any time quickly, never dash water upon it, but rather throw plenty of fresh fuel upon it. Fresh fuel always lowers the heat at first. If all drafts are closed tight, it will lower the heat considerably for quite a time.

In checking a fire, it must be remembered that very sudden cooling will almost surely crack the boiler. If there is danger of an explosion it may be necessary to draw the fire out entirely; but under no circumstances should cold water be thrown on. After drawing the fire close all doors and dampers.

FIRING WITH WOOD.

Always keep the fire door shut as much as possible, as cold air thus admitted will check the fire and ruin the boiler.

Firing with wood is in many ways the exact reverse of firing with coal. The firebox should be filled full of wood at all times. The wood should be thrown in in every direction, in pieces of moderate size, and as it burns away, fresh pieces should be put in at the front so that they will get lighted and ready to burn before being pushed back near the boiler. It often helps a wood fire, too, to stir it with a poker. Wood makes much less ash than coal, and what little accumulates in the grate will not do much harm. Sometimes green wood will not burn because it gets too much cold air. In that case the sticks should be packed as close together as possible, still leaving a place for the air to pass. Also a wood fire, especially one with green wood, should be kept up to a high temperature all the time; for if it is allowed to drop down the wood will suddenly cease to burn at all.

FIRING WITH STRAW.

In firing with straw it is important to keep the shute full of straw all the time so that no cold air can get in on top of the fire. Don't push the straw in too fast, either, but keep it moving at a uniform rate, with small forkfulls. Now and then it is well to turn the fork over and run it down into the fire to keep the fire level. Ashes may be allowed to fill up in rear of ash box, but fifteen inches should be kept clear in front to provide draft. The brick arch may be watched from the side opening in the firebox, and should show a continuous stream of white flame coming over it. If too much straw is forced in, that will check the flame. The flame should never be checked. If damp straw gets against the ends of the flues, it should be scraped off with the poker from side door. Clean the tubes well once a day. The draft must always be kept strong enough to produce a white heat, and if this cannot be done otherwise, a smaller nozzle may be used on the exhaust pipe; but this should be avoided when possible, since it causes back pressure on the engine. Never let the front end of the boiler stand on low ground. Engine should be level, or front end high, if it has a firebox locomotive boiler; if a return flue boiler, be careful to keep it always level. In burning straw take particular notice that the spark screen in stack does not get filled up.

THE ASH PIT.

In burning coal it is exceedingly important that the ashes be kept cleaned out, as the hot cinders falling down on the heap of ashes almost as high as the grate will overheat the grate in a very short time and warp it all out of shape, so ruining it.

With wood and straw, on the contrary, an accumulation of ashes will often help and will seldom do any harm, because no very hot cinders can drop down below the grates, and the hottest part of the fire is some distance above the grates.

STARTING A FIRE.

You must make up your mind that it will take half an hour to an hour or so to get up steam in any boiler that is perfectly cold. The metal expands and shrinks a great deal with the heat and cold, and a sudden application of heat would ruin a boiler in a short time. Hence it is necessary for reasons of engine economy to make changes of temperature, either cooling off or heating up, gradually.

First see that there is water in the boiler.

Start a brisk fire with pine kindlings, gradually putting on coal or wood, as the case may be, and spreading the fire over the grate so that all parts will be covered with glowing coals.

When you have 15 or 20 pounds of steam, start the blower. As has already been described, the blower is a pipe with a nozzle leading from the steam space of the boiler to the smoke stack, and fitted with a globe valve. The force of the steam drives the air out of the stack, causing a vacuum, which is immediately filled by the hot gases from the firebox coming through the boiler tubes. Little is to be gained by using the blower with less than 15 pounds of steam, as the blower has so little strength below that, that it draws off about as much steam as is made and nothing is gained.

The blower is seldom needed when the engine is working, as the exhaust steam should be sufficient to keep the fire going briskly. If it is not, you should conclude that something is the matter. There are times, however, when the blower is required even when the engine is going. For example, if you are working with very light load and small use of steam, the exhaust may be insufficient to keep up the fire; and this will be especially true if the fuel is very poor. In such a case, turn on the blower very slightly. But remember that you are wasting steam if you can get along without the blower.

Examine the nozzle of the blower now and then to see that it does not become limed up, or turned so as to direct the steam to one side of the stack, where its force would be wasted.

Beware, also, of creating too much draft; for too much draft will use up fuel and make little steam.

SMOKE.

Coal smoke is nothing more or less than unburned carbon. The more smoke you get, the less will be the heat from a given amount of fuel. Great clouds of black smoke from an engine all the time are a very bad sign in an engineer. They show that he does not know how to fire. He has not followed the directions already given, to have a thin, hot fire, with few ashes under his grate. Instead, he throws on great shovelsful of coal at a time, and has the coal up to the firebox door. His fuel is always making smoke, which soon clogs up the smoke flues and lessens the amount of steam he is getting. If he had kept his fire very "thin," but very hot, throwing on a small hand shovel of coal at a time, seldom poking his fire except to lift out clinkers or clean away dead ashes under the grate, and keeping his ashpit free from ashes, there would be only a little puff of black smoke when the fresh coal went on, and then the smoke would quickly disappear, while the fire flues would burn clean and not get clogged up with soot.

It is important, however, to keep the small fire flues especially well cleaned out with a good flue cleaner; for all accumulation of soot prevents the heat from passing through the steel, and so reduces the heating capacity of the boiler. Cleaning the tubes with a steam blower is never advisable, as it forms a paste on the tube that greatly impairs its commodity.

SPARKS.

With coal there is little danger of fires caused by sparks from the engine. What sparks there are are heavy and dead, and will even fall on a pile of straw without setting it on fire. On a very windy day, however, when you are running your engine very hard, especially if it is of the direct locomotive boiler type, you want to be careful even with coal.

With wood it is very different; and likewise with straw. Wood and straw sparks are always dangerous, and an engine should never be run for threshing with wood or straw without using a spark-arrester.

It sometimes happens that when coal is used it will give out, and you will be asked to finish your job with wood. In such a case, it is the duty of an engineer to state fully and frankly the danger of firing with wood without a spark arrester, and he should go on only when ordered to do so by the proprietor, after he has been fully warned. In that case all responsibility is shifted from the engineer to the owner.

THE FUSIBLE PLUG.

The careful engineer will never have occasion to do anything to the fusible plug except to clean the scale off from the top of it on the inside of the boiler once a week, and put in a fresh plug once a month. It is put in merely as a precaution to provide for carelessness. The engineer who allows the fusible plug to melt out is by that very fact marked as a careless man, and ought to find it so much the harder to get a job.

As has already been explained, the fusible plug is a plug filled in the middle with some metal that will melt at a comparatively low temperature. So long as it is covered with water, no amount of heat will melt it, since the water conducts the heat away from the metal and never allows it to rise above a certain temperature. When the plug is no longer covered with water, however,—in short, when the water has fallen below the danger line in the boiler—the metal in the plug will fuse, or melt, and make an opening through which the steam will blow into the firebox and put out the fire. However, if the top of the fusible plug has been allowed to become thickly coated with scale, this safety precaution may not work and the boiler may explode. In any case the fusible plug is not to be depended on.

At the same time a good engineer will take every precaution, and one of these is to keep the top of the plug well cleaned. Also he will have an extra plug all ready and filled with composition metal, to put in should the plug in the boiler melt out. Then he will refill the old plug as soon as possible. This may be done by putting a little moist clay in one end to prevent the hot metal from running through, and then pouring into the other end of the plug as much melted metal as it will hold. When cold, tamp down solidly.

LEAKY FLUES.

One common cause of leaky flues is leaving the fire door open so that currents of cold air will rush in on the heated flues and cause them, or some other parts of the boiler, to contract too suddenly. The best boiler made may be ruined in time by allowing cold currents of air to strike the heated interior. Once or twice will not do it; but continually leaving the fire door open will certainly work mischief in the end.

Of course, if flues in a new boiler leak, it is the fault of the boiler maker. The tubes were not large enough to fill the holes in the tube sheets properly. But if a boiler runs for a season or so and then the flues begin to leak, the chances are that it is due to the carelessness of the engineer. It may be he has been making his fires too hot; it may be leaving the firebox door open; it may be running the boiler at too high pressure; it may be blowing out the boiler when it is too hot; or blowing out the boiler when there is still some fire in the firebox; it may be due to lime encrusted on the inside of the tube sheets, causing them to overheat. Flues may also be made to leak by pumping cold water into the boiler when the water inside is too low; or pouring cold water into a hot boiler will do it. Some engineers blow out their boilers to clean them, and then being in a hurry to get to work, refill them while the metal is hot. The flues cannot stand this, since they are thinner than the shell of the boiler and cool much more quickly; hence they will contract much faster than the rest of the boiler and something has to come loose.

Once a flue starts to leaking, it is not likely to stop till it has been repaired; and one leaky flue will make others leak.

Now what shall you do with a leaky flue?

To repair a leaky flue you should have a flue expander and a calking tool, with a light hammer. If you are small enough you will creep in at the firebox door with a candle in your hand. First, clean off the ends of the flues and flue sheet with some cotton waste. Then force the expander into the leaky flue, bringing the shoulder well up against the end of the flue. Then drive in the tapering pin. Be very careful not to drive it in too far, for if you expand the flue too much, you will strain the flue sheet and cause other flues to leak. You must use your judgment and proceed cautiously. It is better to make two or three trials than to spoil your boiler by bad work. The roller expander is preferable to the Prosser in the hands of a novice. The tube should be expanded only enough to stop the leak. Farther expanding will only do injury.

When you think the flue has been expanded enough, hit the pin a side blow to loosen it. Then turn the expander a quarter round, and drive in the pin again. Loosen up and continue till you have turned the expander entirely around.

Finally remove the expander, and use the calking tool to bead the end. It is best, however, to expand all leaky flues before doing any beading.

The beading is done by placing the guide or gauge inside the flue, and then pounding the ends of the flue down against the flue sheet by light blows. Be very careful not to bruise the flue sheet or flues, and use no heavy blows, nor even a heavy hammer. Go slowly and carefully around the end of each flue; and if you have done your work thoroughly and carefully the flues will be all right. But you should test your boiler before steaming up, to make sure that all the leaks are stopped, especially if there have been bad ones.

There are various ways to testing a boiler. If waterworks are handy, connect the boiler with a hydrant and after filling the boiler, let it receive the hydrant pressure. Then examine the calked flues carefully, and if you see any seeping of water, use your beader lightly till the water stops. In case no waterworks with good pressure are at hand, you can use a hydraulic pump or a good force pump.

The amount of pressure required in testing a boiler should be that at which the safety valve is set to blow off, say 110 to 130 lbs. This will be sufficient.

If you are in the field with no hydrant or force pump handy, you may test your boiler in this way: Take off the safety valve and fill the boiler full of water through the safety valve opening. Then screw the safety back in its place. You should be sure that every bit of space in the boiler is filled entirely full of water, with all openings tightly closed. Then get back in the boiler and have a bundle of straw burned under the firebox, or under the waist of the boiler, so that at some point the water will be slightly heated. This will cause pressure. If your safety valve is in perfect order, you will know as soon as water begins to escape at the safety valve whether your flues are calked tight enough or not.

The water is heated only a few degrees, and the pressure is cold water pressure. In very cold weather this method cannot be used, however, as water has no expansive force within five degrees of freezing.

The above methods are not intended for testing the safety of a boiler, but only for testing for leaky flues. If you wish to have your boiler tested, it is better to get an expert to do it.

CHAPTER V.

HOW TO MANAGE A TRACTION ENGINE.

A traction engine is usually the simplest kind of an engine made. If it were not, it would require a highly expert engineer to run it, and this would be too costly for a farmer or thresherman contractor. Therefore the builders of traction engines make them of the fewest possible parts, and in the most durable and simple style. Still, even the simplest engine requires a certain amount of brains to manage it properly, especially if you are to get the maximum of work out of it at the lowest cost.

If the engine is in perfect order, about all you have to do is to see that all bearings are properly lubricated, and that the automatic oiler is in good working condition. But as soon as an engine has been used for a certain time, there will be wear, which will appear first in the journals, boxes and valve, and it is the first duty of a good engineer to adjust these. To adjust them accurately requires skill; and it is the possession of that skill that goes to make a real engineer.

Your first attention will probably be required for the cross-head and crank boxes or brasses. The crank box and pin will probably wear first; but both the cross-head and crank boxes are so nearly alike that what is said of one will apply to the other.

You will find the wrist box in two parts. In a new engine these parts do not quite meet. There is perhaps an eighth of an inch waste space between them. They are brought up to the box in most farm engines by a wedge-shaped key. This should be driven down a little at a time as the boxes wear, so as to keep them snug up to the pin, though not too tight.

You continue to drive in the key and tighten up the boxes as they wear until the two halves come tight together. Then you can no longer accomplish anything in this way.

When the brasses have worn so that they can be forced no closer together, they must be taken off and the ends of them filed where they come together. File off a sixteenth of an inch from each end. Do it with care, and be sure you get the ends perfectly even. When you have done this you will have another eighth of an inch to allow for wear.

Now, by reflection you will see that as the wrist box wears, and the wedge-shaped key is driven in, the pitman (or piston arm) is lengthened to the amount that the half of the box farthest from the piston has worn away. When the brasses meet, this will amount to one-sixteenth of an inch.

Now if you file the ends off and the boxes wear so as to come together once more, the pitman will have been shortened one-eighth of an inch; and pretty soon the clearance of the piston in the cylinder will have been offset, and the engine will begin to pound. In any case, the clearance at one end of the cylinder will be one-sixteenth or one-eighth of an inch less, and in the other end one-sixteenth or one-eighth of an inch more. When this is the case you will find that the engine is not working well.

To correct this, when you file the brasses either of the cross-head box or the crank box you must put in some filling back of the brass farthest from the piston, sufficient to equalize the wear that has taken place, that is, one-sixteenth of an inch each time you have to file off a sixteenth of an inch. This filling may be some flat pieces of tin or sheet copper, commonly called shims, and the process is called shimming. As to the front half of the box, no shims are required, since the tapering key brings that box up to its proper place.

Great care must be exercised when driving in the tapering key or wedge to tighten up the boxes, not to drive it in too hard. Many engineers think this is a sure remedy for "knocking" in an engine, and every time they hear a knock they drive in the crank box key. Often the knock is from some other source, such as from a loose fly wheel, or the like. Your ear is likely to deceive you; for a knock from any part of an engine is likely to sound as if it came from the crank box. If you insist on driving in the key too hard and too often, you will ruin your engine.

In tightening up a key, first loosen the set screw that holds the key; then drive down the key till you think it is tight; then drive it back again, and this time force it down with your fist as far as you can. By using your fist in this way after you have once driven the pin in tight and loosened it again you may be pretty certain you are not going to get it so tight it will cause the box to heat.

WHAT CAUSES AN ENGINE TO KNOCK.

The most common sign that something is loose about an engine is "knocking," as it is called. If any box wears a little loose, or any wheel or the like gets a trifle loose, the engine will begin to knock.

When an engine begins to knock or run hard, it is the duty of the engineer to locate the knock definitely. He must not guess at it. When he has studied the problem out carefully, and knows where the knock is, then he may proceed to remedy it. Never adjust more than one part at a time.

As we have said, a knock is usually due to looseness somewhere. The journals of the main shaft may be loose and cause knocking. They are held in place by set bolts and jam nuts, and are tightened by simply screwing up the nuts. But a small turn of a nut may make the box so tight it will begin to heat at once. Great care should be taken in tightening up such a box to be sure not to get it too tight. Once a box begins to cut, it should be taken out and thoroughly cleaned.

Knocking may be due to a loose eccentric yoke. There is packing between the two halves of the yoke, and to tighten up you must take out a thin layer of this packing. But be careful not to take out too much, or the eccentric will stick and begin to slip.

Another cause of knocking is the piston rod loose in the cross-head. If the piston rod is keyed to the cross-head it is less liable to get loose than if it were fastened by a nut; but if the key continues to get loose, it will be best to replace it with a new one.

Unless the piston rod is kept tight in the cross-head, there is liability of a bad crack. A small strain will bring the piston out of the cross-head entirely, when the chances are you will knock out one or both cylinder-heads. If a nut is used, there will be the same danger if it comes off. It should therefore be carefully watched. The best way is to train the ear to catch any usual sound, when loosening of the key or nut will be detected at once.

Another source of knocking is looseness of the cross-head in the guides. Provision is usually made for taking up the wear; but if there is not, you can take off the guides and file them or have them planed off. You should take care to see that they are kept even, so that they will wear smooth with the crosshead shoes.

If the fly-wheel is in the least loose it will also cause knocking, and it will puzzle you not a little to locate it. It may appear to be tight; but if the key is the least bit too narrow for the groove in the shaft, it will cause an engine to bump horribly, very much as too much "lead" will.

LEAD.

We have already explained what "lead" is. It is opening of the port at either end of the steam cylinder allowed by the valve when the engine is on a dead centre. To find out what the lead is, the cover of the steam chest must be taken off, and the engine placed at each dead centre in succession. If the lead is greater at one end than it is at the other, the valve must be adjusted to equalize it. As a rule the engine is adjusted with a suitable amount of lead if it is equalized. The correct amount of lead varies with the engine and with the port opening. If the port opening is long and narrow, the lead should obviously be less than if the port is short and wide.

If the lead is insufficient, there will not be enough steam let into the cylinder for cushion, and the engine will knock. If there is too much lead the speed of the engine will be lessened, and it will not do the work it ought. To adjust the lead *de novo* is by no means an easy task.

HOW TO SET A SIMPLE VALVE.

In order to set a valve the engine must be brought to a dead centre. This cannot be done accurately by the eye. An old engineer* gives the following directions for finding the dead centre accurately. Says he: "First provide yourself with a 'tram.' This is a rod of one-fourth inch iron about eighteen inches long, with two inches at one end bent over to a sharp angle. Sharpen both ends to a point. Fasten a block of hard wood somewhere near the face of the fly-wheel, so that when the straight end of your tram is placed at a definite point in the block, the hooked end will reach the crown of the fly-wheel. The block must be held firmly in its place, and the tram must always touch it at exactly the same point.

"You are now ready to set about finding the dead centre. In doing this, remember to turn the fly-wheel always in the same direction.

"Bring the engine over till it nearly reaches one of the dead centres, but not quite. Make a distinct mark across the cross-head and guides. Also go around to the fly-wheel, and placing the straight end of the tram at the selected point on the block of wood, make a mark across the crown or centre of face of the fly-wheel. Now turn your engine past the centre, and on to a point at which the mark on the cross head will once more exactly correspond with the line on the guides, making a single straight line. Once more place the tram as before and make another mark across the crown of the fly-wheel. By use of dividers, find the exact centre between the two marks made on the fly-wheel, and mark this point distinctly with a centre punch. Now bring the fly-wheel to the point where the tram, set with its straight end at the required point on the block of wood, will touch this point with the hooked end, and you will have one of the dead centres.

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*J. H. Maggard.

"Turn the engine over and proceed in the same way to find the other dead centre."

Now, setting the engine on one of the dead centres, remove the cover of the steam chest and proceed to set your valve.

Assuming that the engine maker gave the valve the proper amount of lead in the first place, you can proceed on the theory that it is merely necessary to equalize the lead at both ends. Assume some convenient lead, as one-sixteenth of an inch, and set the valve to that. Then turn the engine over and see if the lead at the other end is the same. If it is the same, you have set the valve correctly. If it is less at the other end, you may conclude that the lead at both ends should be less than one-sixteenth of an inch, and must proceed to equalize it. This you can do by fitting into the open space a little wedge of wood, changing the valve a little until the wedge goes in to just the same distance at each end. Then you may know that the lead at one end is the same as at the other end. You can mark the wedge for forcing it against the metal, or mark it against the seat of the valve with a pencil.

The valve is set by loosening the set screws that hold the eccentric on the shaft. When these are loosened up the valve may be moved freely. When it is correctly set the screws should be tightened, and the relative position of the eccentric on the shaft may be permanently marked by setting a cold chisel so that it will cut into the shaft and the eccentric at the same time and giving it a smart blow with the hammer, so as to make a mark on both the eccentric and the shaft. Should your eccentric slip at any time in the future, you can set your valve by simply bringing the mark on the eccentric so that it will correspond with the mark on the shaft. Many engines have such a mark made when built, to facilitate setting a valve should the eccentric become loose.

These directions apply only to setting the valve of a single eccentric engine.

HOW TO SET A VALVE ON A DOUBLE ECCENTRIC ENGINE.

In setting a valve on a reversible or double eccentric engine, the link may cause confusion, and you may be trying to set the valve to run one way when the engine is set to run the other.

The valve on such an engine is exactly the same as on a single eccentric engine. Set the reverse lever for the engine to go forward. Then set the valve exactly as with a single eccentric engine. When you have done so, tighten the eccentric screws so that they will hold temporarily, and set the reverse lever for the engine to go backward. Then put the engine on dead centres and see if the valve is all right at both ends. If it is, you may assume that it is correctly set, and tighten eccentric screws, marking both eccentrics as before.

As we have said, most engines are marked in the factory, so that it is not a difficult matter to set the valves, it being necessary only to bring the eccentric around so that the mark on it will correspond with the mark on the shaft.

You can easily tell whether the lead is the same at both ends by listening to the exhaust. If it is longer at one end than the other, the valve is not properly set.

SLIPPING OF THE ECCENTRIC OR VALVE.

If the eccentric slips the least bit it may cause the engine to stop, or to act very queerly. Therefore the marks on the shaft and on the eccentric should be watched closely, and of course all grease and dirt should be kept wiped off, so that they can be seen easily. Then the jam nuts should be tightened up a little from time to time.

If the engine seems to act strangely, and yet the eccentrics are all right, look at the valve in the steam chest. If the valve stem has worked loose from the valve, trouble will be caused. It may be held in place by a nut, and the nut may work off; or the valve may be held by a clamp and pin, and the pin may work loose. Either will cause loss of motion, and perhaps a sudden stopping of the engine.

USE OF THE CYLINDER STEAM COCKS.

It is a comparatively simple matter to test a steam cylinder by use of the cylinder cocks. To do this, open both cocks, place the engine on the forward center, and turn on a little steam. If the steam blows out at the forward cock, we may judge that our lead is all right. Now turn the engine to the back center and let on the steam. It should blow out the same at the back cock. A little training of the ear will show whether the escape of steam is the same at both ends. Then reverse the engine, set it on each center successfully, and notice whether the steam blows out from one cock at a time and in the same degree of force.

If the steam blows out of both cocks at the same time, or out of one cock on one center, but not out of the other cock on its corresponding center, we may know something is wrong. The valve does not work properly.

We will first look at the eccentrics and see that they are all right. If they are, we must open the steam chest, first turning off all steam. Probably we shall find that the valve is loose on the valve rod, if our trouble was that the steam blew out of the cock but did not out of the other when the engine was on the opposite center.

If our trouble was that steam blew out of both cocks at the same time, we may conclude either that the cylinder rings leak or else the valve has cut its seat. It will be a little difficult to tell which at first sight. In any case it is a bad thing, for it means loss of power and waste of steam and fuel. To tell just where the trouble is you must take off the cylinder head, after setting the engine on the forward center. Let in a little steam from the throttle. If it blows through around the rings, the trouble is with them; but if it blows through the valve port, the trouble is with the valve and valve seat.

If the rings leak you must get a new set if they are of the self-adjusting type. But if they are of the spring or adjusting type you can set them out yourself; but few engines now use the latter kind of rings, so a new pair will probably be required.

If the trouble is in the valve and valve seat, you should take the valve out and have the seat planed down, and the valve fitted to the seat. This should always be done by a skilled mechanic fully equipped for such work, as a novice is almost sure to make bad work of it. The valve seat and valve must be scraped down by the use of a flat piece of very hard steel, an eighth of an inch thick and about 3 by 4 inches in size. The scraping edge must be absolutely straight. It will be a slow and tedious process, and a little too much scraping on one side or the other will prevent a perfect fit. Both valve and valve seat must be scraped equally. Novices sometimes try to reseat a valve by the use of emery. This is very dangerous and is sure to ruin the valve, as it works into the pores of the iron and causes cutting.

LUBRICATION.

A knowledge of the difference between good oil and poor oil, and of how to use oil and grease, is a prime essential for an engineer.

First let us give a little attention to the theory of lubrication. The oil or grease should form a lining between the journal and its pin or shaft. It is in the nature of a slight and frictionless cushion at all points where the two pieces of metal meet.

Now if oil is to keep its place between the bearing and the shaft or pin it must stick tight to both pieces of metal, and the tighter the better. If the oil is light the forces at work on the bearings will force the oil away and bring the metals together. As soon as they come together they begin to wear on each other, and sometimes the wear is very rapid. This is called "cutting." If a little sand or grit gets into the bearing, that will help the cutting wonderfully, and more especially if there is no grease there.

For instance, gasoline and kerosene are oils, but they are so light they will not stick to a journal, and so are valueless for lubricating. Good lubricating oil will cost a little more than cheap oil which has been mixed with worthless oils to increase its bulk without increasing its cost. The higher priced oil will really cost less in the end, because there is a larger percentage of it which will do service. A good engineer will have it in his contract that he is to be furnished with good oil.

Now an engine requires two different kinds of oil, one for the bearings, such as the crank pin, the cross-head and journals, and quite a different kind for lubricating the steam cylinder.

It is extremely important that the steam cylinder should be well lubricated; and this cannot be done direct. The oil must be carried into the valve and cylinder with steam. The heat of the steam, moreover, ranging from about 320 degrees Fahr. for 90 lbs. pressure to 350 degrees for 125 lbs. of pressure, will quickly destroy the efficacy of a poor oil, and a good cylinder oil must be one that will stick to the cylinder and valve seat under this high temperature. It must have staying qualities.

The link reverse is one of the best for its purpose; but it requires a good quality of oil on the valve for it to work well. If the valve gets a little dry, or the poor oil used does not serve its purpose properly, the link will begin to jump and pound. This is a reason why makers are substituting other kinds of reverse gear in many ways not as good, but not open to this objection. If a link reverse begins to pound when you are using good oil, and the oiler is working properly, you may be sure something is the matter with the valve or the gear.

A good engineer will train his ear so that he will detect by simply listening at the cylinder whether everything is working exactly as it ought. For example, the exhaust at each end of the cylinder, which you can hear distinctly, should be the same and equal. If the exhaust at one end is less than it is at the other, you may know that one end of the cylinder is doing more work than the other. And also any little looseness or lack of oil will signify itself by the peculiar sound it will cause.

While the cylinder requires cylinder oil, the crank, cross-head and journals require engine oil, or hard grease. The use of hard grease is rapidly increasing, and it is highly to be recommended. With a good automatic spring grease cup hard grease will be far less likely to let the bearings heat than common oil will. At the same time it will be much easier to keep an engine clean if hard grease is used.

An old engineer* gives the following directions for fitting a grease cup on a box not previously arranged for one: "Remove the journal, take a gouge and cut a clean groove across the box, starting at one corner, about one-eighth of an inch from the point of the box, and cut diagonally across, coming out at the opposite corner on the other end of the box. Then start at the opposite corner and run through as before, crossing the first groove in the center of the box. Groove both halves of the box the same, being careful not to cut out at either end, as this will allow the grease to escape from the box and cause unnecessary waste. The shimming or packing in the box should be cut so as to touch the journal at both ends of the box, but not in the center or between these two points. So when the top box is brought down tight this will form another reservoir for the grease. If the box is not tapped directly in the center for the cup, it will be necessary to cut another groove from where it is tapped into the grooves already made. A box prepared in this way and carefully polished inside, will require little attention if you use good grease."

A HOT BOX.

When a box heats in the least degree, it is a sign that for lack of oil or for some other reason the metals are wearing together.

The first thing to do, of course, is to see that the box is supplied with plenty of good oil or grease.

If this does not cause the box to cool off, take it apart and clean it thoroughly. Then coat the journal with white lead mixed with good oil. Great care should be exercised to keep all dirt or grit out of your can of lead and away from the bearing.

Replace the oil or grease cup, and the box will soon cool down.

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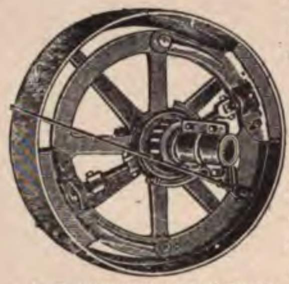
*J. H. Maggard.

THE FRICTION CLUTCH.

Nearly all traction engines are now provided with the friction clutch for engaging the engine with the propelling gear. The clutch is usually provided with wooden shoes, which are adjustable as they wear; and the clutch is thrown on by a lever, conveniently placed.


A. W. STEVENS CO. FRICTION CLUTCH.

Before running an engine, you must make sure that the clutch shoes are properly adjusted. Great care must be taken to be sure that both shoes will come in contact with the friction wheel at the same instant; for if one shoe touches the wheel before the other the clutch will probably slip.

The shoes should be so set as to make it a trifle difficult to draw the lever clear back.

To regulate the shoes on the Rumely engine, for example, first throw the friction in. The nut on the top of the toggle connecting the sleeve of the friction with the shoe must then be loosened, and the nut below the shoe tightened up, forcing the shoe toward the wheel. Both shoes should be carefully adjusted so that they will engage the band wheel equally and at exactly the same time.

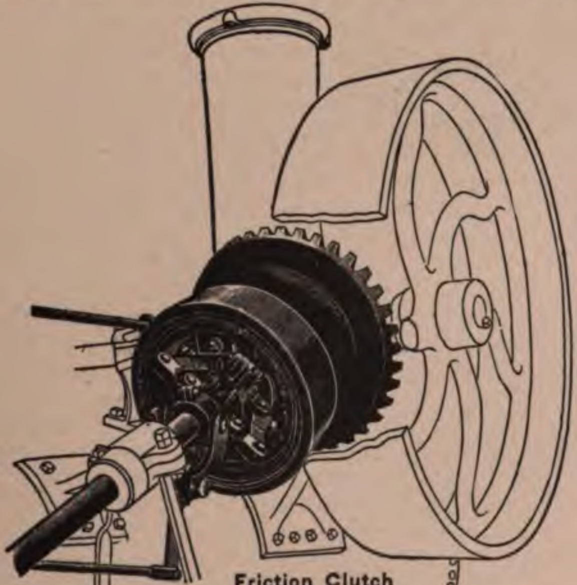
To use the friction clutch, first start the engine, throwing the throttle gradually wide open. When the engine is running at its usual speed, slowly bring up the clutch until the gearing is fully engaged, letting the engine start slowly and smoothly, without any jar.

Traction engines having the friction clutch are also provided with a pin for securing a rigid connection, to be used in cases of necessity, as when the clutch gets broken or something about it gives out, or you have difficulty in making it hold when climbing hills. This pin is a simple round or square pin that can be placed through a hole in one of the spokes of the band wheel until it comes into a similar opening in the friction wheel. When the pin is taken out, so as to disconnect the wheels, it must be entirely removed, not left sticking in the hole, as it is liable to catch in some other part of the machinery.

MISCELLANEOUS SUGGESTIONS.

Be careful not to open the throttle valve too quickly, or you may throw off the driving belt. You may also stir up the water and cause it to pass over with the steam, starting what is called "priming."

Always open your cylinder cocks when you stop, to make sure all water has been drained out of the cylinder; and see that they are open when you start, of course closing them as soon as the steam is let in.



AULTMAN & TAYLOR FRICTION CLUTCH.

When you pull out the ashes always have a pail of water ready, for you may start a fire that will do no end of damage.

If the water in your boiler gets low and you are wait-ing for the tank to come up, don't think you "can keep on a little longer," but stop your engine at once. It is better to lose a little time than run the risk of an explosion that will ruin your reputation as an engineer and cause your employer a heavy expense.

Never start the pump when the water in the boiler is low.

Be sure the exhaust nozzle does not get limed up, and be sure the pipe where the water enters the boiler from the heater is not limed up, or you may split a heater pipe or knock out a check valve.

Never leave your engine in cold weather without draining off all the water; and always cover up your engine when you leave it.

Never disconnect the engine with a leaky throttle.

Keep the steam pressure steady, not varying more than 10 to 15 lbs.

If called on to run an old boiler, have it thoroughly tested before you touch it.

Always close your damper before pulling through a stack yard.

Examine every bridge before you pull on to it.

Do not stop going down a steep grade.

CHAPTER VI.

HANDLING A TRACTION ENGINE ON THE ROAD.

It is something of a trick to handle a traction engine on the road. The novice is almost certain to run it into a ditch the first thing, or get stuck on a hill, or in a sand patch or a mudhole. Some attention must therefore be paid to handling a traction engine on the road.

In the first place, never pull the throttle open with a jerk, nor put down the reverse lever with a snap. Handle your engine deliberately and thoughtfully, knowing beforehand just what you wish to do and how you will do it. A traction engine is much like an ox; try to goad it on too fast and it will stop and turn around on you. It does its best work when moving slowly and steadily, and seldom is anything gained by rushing.

The first thing for an engineer to learn is to handle his throttle. When an engine is doing work the throttle should be wide open; but on the road, or in turning, backing, etc., the engineer's hand must be on the throttle all the time and he must exercise a nice judgment as to just how much steam the engine will need to do a certain amount of work. This the novice will find out best by opening the throttle slowly, taking all the time he needs, and never allowing any one to hurry him.

As an engineer learns the throttle, he gradually comes to have confidence in it. As it were, he feels the pulse of the animal and never makes a mistake. Such an engineer always has power to spare, and never wastes any power. He finds that a little is often much better than too much.

The next thing to learn is the steering wheel. It has tricks of its own, which one must learn by practice. Most young engineers turn the wheel altogether too much. If you let your engine run slowly you will have time to turn the wheel slowly, and accomplish just what you want to do. If you hurry you will probably have to do your work all over again, and so lose much more time in the end than if you didn't hurry.

Always keep your eyes on the front wheels of the engine, and do not turn around to see how your load is coming on. Your load will take care of itself if you manage the front wheels all right, for they determine where you are to go.

In making a hard turn, especially, go slow. Then you will run no chance of losing control of your engine, and you can see that neither you nor your load gets into a ditch.

GETTING INTO A HOLE.

You are sure sooner or later to get into a hole in the road, for a traction engine is so heavy it is sure to find any soft spot in the road there may be.

As to getting out of a hole, observe in the first place that you must use your best judgment.

First, never let the drive wheels turn round without doing any work. The more they spin round without helping you, the worse it will be for you.

Your first thought must be to give the drive wheels something they can climb on, something they can stick to. A heavy chain is perhaps the very best thing you can put under them. But usually on the road you have no chain handy. In that case, you must do what you can. Old hay or straw will help you; and so will old rails or any old timber.

Spend your time trying to give your wheels something to hold to, rather than trying to pull out. When the wheels are all right, the engine will go on its way without any trouble whatever. And do not half do your work of fixing the wheels before you try to start. See that both wheels are secure before you put on a pound of steam. Make sure of this the first time you try, and you will save time in the end. If you fix one wheel and don't fix the other, you will probably spoil the first wheel by starting before the other is ready.

Should you be where your engine will not turn, then you are stuck indeed. You must lighten your load or dig a way out.

BAD BRIDGES.

A traction engine is so heavy that the greatest care must be exercised in crossing bridges. If a bridge floor is worn, if you see rotten planks in it, or liability of holes, don't pull on to that bridge without taking precautions.

The best precaution is to carry with you a couple of planks sixteen feet long, three inches thick in the middle, tapering to two inches at the ends; also a couple of planks eight feet long and two inches thick, the latter for culverts and to help out on long bridges.

Before pulling on to a bad looking bridge, lay down your planks, one for each pair of wheels of the engine to run on. Be exceedingly careful not to let the engine drop off the edge of these planks on the way over, or pass over the ends on to the floor of the bridge. If one pair of planks is too short, use your second pair.

Another precaution which it is wise to take is to carry fifty feet of good, stout hemp rope, and when you come to a shaky bridge, attach your separator to the engine by this rope at full length, so that the engine will have crossed the bridge before the weight of the separator comes upon it.

Cross a bad bridge very slowly. Nothing will be gained by hurrying. There should especially be no sudden jerks or starts.

SAND PATCHES.

A sandy road is an exceedingly hard road to pull a load over.

In the first place, don't hurry over sand. If you do you are liable to break the footing of the wheels, and then you are gone.

In the second place, keep your engine as steady and straight as possible, so that both wheels will always have an equal and even bearing. They are less liable to slip if you do. It is useless to try to "wiggle" over a sand patch. Slow, steady, and even is the rule.

If your wheels slip in sand, a bundle of straw or hay, especially old hay, will be about the best thing to give them a footing.

HILLS.

In climbing hills take the same advice we have given you all along: Go slow. Nothing is gained by rushing at a hill with a steam engine. Such an engine works best when its force is applied steadily and evenly, a little at a time.

If you have a friction clutch, as you probably will have, you should be sure it is in good working order before you attempt to climb hills. It should be adjusted to a nicety, as we have already explained. When you come to a bad hill it would probably be well to put in the tight gear pin; or use it altogether in a hilly country.

When the friction clutch first came into use, salesmen and others used to make the following recommendation (a recommendation which we will say right here is bad). They said, when you come to an obstacle in the road that you can't very well get your engine over, throw off your friction clutch from the road wheels, let your engine get under good headway running free, and then suddenly put on the friction clutch and jerk yourself over the obstacle.

Now this is no doubt one way to get over an obstacle; but no good engineer would take his chances of spoiling his engine by doing any such thing with it. Some part of it would be badly strained by such a procedure; and if this were done regularly all through a season, an engine would be worth very little at the end of the season.

CHAPTER VII.

POINTS FOR THE YOUNG ENGINEER.

QUESTIONS AND ANSWERS.

THE BOILER.

Q. How should water be fed to a boiler?

A. In a steady stream, by use of a pump or injector working continuously and supplying just the amount of water required. By this means the water in the boiler is maintained at a uniform level, and produces steam most evenly and perfectly.

Q. Why should pure water be used in a boiler ?

A. Because impure water, or hard water, forms scales on the boiler flues and plates, and these scales act as non-conductors of heat. Thus the heat of the furnace is not able to pass easily through the boiler flues and plates to the water, and your boiler becomes what is called "a hard steamer."

Q. What must be done to prevent the formation of scale?

A. First, use some compound that will either prevent scale from forming, or will precipitate the scale forming substance as a soft powder that can easily be washed off. Sal soda dissolved in the feed water is recommended, but great care should be exercised in the use of sal soda not to use too much at a time, as it may cause a boiler to foam. Besides using a compound, clean your boiler often and regularly with a hand hose and a force pump, and soak it out as often as possible by using rain water for a day or two, especially before cleaning. Rain water will soften and bring down the hard scale far better than any compound.

Q. How often should you clean your boiler?

A. As often as it needs it, which will depend upon the work you do and the condition of the water. Once a week is usually often enough if the boiler is blown down a little every day. If your water is fairly good, once a month will be often enough. A boiler should be blown off about one gauge at a time two or three times a day with the blow-off if the water is muddy.

Q. How long should the surface blow-off be left open?

A. Only for a few seconds, and seldom longer than a minute. The surface blow-off carries off the scum that forms on the water, and other impurities that rise with the scum.

Q. How do you clean a boiler by blowing off?

A. When the pressure has been allowed to run down open the blow-off valve at the bottom of the boiler and let the water blow out less than a minute, till the water drops out of sight in the water gauges, or about two and one-half inches. Blown off more is only a waste of heat and fuel.

Q. What harm will be done by blowing off a boiler under a high pressure of steam?

A. The heat in the boiler while there is such a pressure will be so great that it will bake the scale on the inside of the boiler, and it will be very difficult to remove it afterward. After a boiler has been blown off the scale should be for the most part soft, so that it can be washed out by a hose and force pump.

Q. Why should a hot boiler never be filled with cold water?

A. Because the cold water will cause the boiler to contract more in some places than in others, and so suddenly that the whole will be badly strained. Leaky flues are made in this way, and the life of a boiler greatly shortened. As a rule a boiler should be filled only when the metal and the water put into it are about at the same temperature.

Q. After a boiler has been cleaned, how should the manhole and manhole plates be replaced?

A. They are held in position by a bolt passing through a yoke that straddles the hole; but to be steam and water tight they must have packing all around the junction of the plate with the boiler. The best packing is sheet rubber cut in the form of a ring just the right size for the bearing surface. Hemp or cotton packing are also used, but they should be free from all lumps and soaked in oil. Do not use any more than is absolutely needed. Be careful, also, to see that the bearings of the plate and boiler are clean and smooth, with all the old packing scraped off. Candle wick saturated with red lead is next best to rubber as packing.

Q. What are the chief duties of an engineer in care of a boiler?

A. First, to watch all gauges, fittings, and working parts, to see that they are in order; try the gauge cocks to make sure the water is at the right height; try the safety valve from time to time to be sure it is working; see that there are no leaks, that there is no rusting or wearing of parts, or to replace parts when they do begin to show wear; to examine the check valve frequently to make sure no water can escape through it from the boiler; take precautions against scale and stoppage of pipes by scale; and keep the fire going uniformly, cleanly, and in an economical fashion.

Q. What should you do if the glass water gauge breaks?

A. Turn off the gauge cocks above and below, the lower one first so that the hot water will not burn you. You may put in a new glass and turn on gauge cocks at once. Turn on the lower or water cock first, then the upper or steam cock. You may go on without the glass gauge, however, using the gauge cocks or try cocks every few minutes to make sure the water is at the right height, neither too high nor too low.

Q. Why is it necessary to use the gauge cocks when the glass gauge is all right?

A. First, because you cannot otherwise be sure that the glass gauge is all right; and, secondly, because if you do not use them frequently they are likely to become scaled up so that you cannot use them in case of accident to the glass gauge.

Q. If a gauge cock gets leaky, what should be done?

A. Nothing until the boiler has cooled down. Then if the leak is in the seat, take it out and grind and refit it;

if the leak is where the cock is screwed into the boiler, tighten it up another turn and see if that remedies the difficulty. If it does not you will probably have to get a new gauge cock.

Q. Why not screw up a gauge cock while there is a pressure of steam on?

A. The cock might blow out and cause serious injury to yourself or some one else. Make it a rule never to fool with any boiler fittings while there is a pressure of steam on the boiler. It is exceedingly dangerous.

Sometimes a gauge cock gets broken off accidentally while the boiler is in use. If such an accident happens, bank the fire by closing the draft and covering the fire with fresh fuel or ashes. Stop the engine and let the water blow out of the hole till only steam appears; then try to plug the opening with a long whitewood or poplar, or even a pine stick (six or eight feet long), one end of which you have whittled down to about the size of the hole. When the steam has been stopped the stick may be cut off close to the boiler and the plug driven in tight. If necessary you may continue to use the boiler in this condition until a new cock can be put in.

Q. What should you do when a gauge cock is stopped up?

A. Let the steam pressure go down, and then take off the front part and run a small wire into the passage, working the wire back and forth until all scale and sediment has been removed.

Q. What should you do when the steam gauge gets out of order.

A. If the steam gauge does not work correctly, or you suspect it does not, you may test it by running the steam up until it blows off at the safety valve. If the steam gauge does not indicate the pressure at which the safety valve is set to pop off, and you have reason to suppose the safety valve is all right, you may conclude that there is something the matter with the steam gauge. In that case either put in a new one, or, if you have no extra steam gauge on hand, shut down your boiler and engine till you can get your steam gauge repaired. Sometimes this can be done simply by adjusting the pointer, which may have got loose, and you can test it by attaching it to another boiler which has a steam gauge that is all right and by which you can check up yours. It is VERY DANGEROUS to run your boiler without a steam gauge, depending on the safety valve. Never allow the slightest variation in correctness of the steam gauge without repairing it at once. It will nearly always be cheaper in these days to put in a new gauge rather than try to repair the old one.

Q. What should you do if the pump fails to work?

A. Use the injector.

Q. What should you do if there is no injector?

A. Stop the engine at once and bank the fire with damp ashes, especially noting that the water does not fall below the bottom of the glass gauge. Then examine the pump. First see if the plunger leaks air; if it is all right, examine the check valves, using the little drain cock as previously explained to test the upper ones, for the valves may have become worn and will leak; third, if the check valves are all right, examine the supply pipe, looking at the strainer, observing whether suction takes place when the pump is worked, etc. There may be a leak in the suction hose somewhere during its course where air can get in, or it may become weak and collapse under the force of the atmosphere, or the lining of the suction pipe may have become torn or loose. The slightest leak in the suction pipe will spoil the working of the pump. Old tubing should never be used, as it is sure to give trouble. Finally, examine the delivery pipe. Close the cock or valve next the boiler, and examine the boiler check valve; notice whether the pipe is getting limed up. If necessary, disconnect the pipe and clean it out with a stiff wire. If everything is all right up to this point, you must let the boiler cool off, blow out the water, disconnect the pipe between the check and the boiler, and thoroughly clean the delivery pipe into the boiler. Stoppage of the delivery pipe is due to deposits of lime from the heating of the water in the heater. Stoppage from this source will be gradual, and you will find less and less water going into your boiler from your pump until none flows at all. From this you may guess the trouble.

Q. How may the communication with the water gauge always be kept free from lime?

A. By blowing it off through the drain cock at the bottom. First close the upper cock and blow off for a few seconds, the water passing through the lower cock; then close the lower cock and open the upper one, allowing the steam to blow through this and the drain cock for a few seconds. If you do this every day or oftener you will have no trouble.

Q. Should the water get low for any reason, what should be done?

A. Close all dampers tight so as to prevent all draft, and bank the fire with fresh fuel or with ashes (damp ashes are the best if danger is great). Then let the boiler cool down before putting in fresh water. Banking the fire is better than drawing or dumping it, as either of these make the heat greater for a moment or two, and that additional heat might cause an explosion. Dashing cold water upon the fire is also very dangerous and in every way unwise. Again, do not open the safety valve, for that also, by relieving some of the pressure on the superheated water, might cause it to burst suddenly into steam and so cause an explosion.

Q. Under such circumstances, would you stop the engine?

A. No; for a sudden checking of the outflow of steam might bring about an explosion. Do nothing but check the heat as quickly and effectively as you can by banking or covering the fires.

Q. Why not turn on the feed water?

A. Because the crown sheet of the boiler has become overheated, and any cold water coming upon it would cause an explosion. If the pump or injector are running, of course you may let them run, and the boiler will gradually refill as the heat decreases. Under such circumstances low water is due to overheating the boiler.

Q. Would not the fusible plug avert any disaster from low water?

A. It might, and it might not. The top of it is liable to get coated with lime so that the device is worthless. You should act at all times precisely as if there were no fusible plug. If it ever does avert an explosion you may be thankful, but averting explosions by taking such means as we have suggested will be far better for an engineer's reputation.

Q. Would not the safety valve be a safeguard against explosion?

A. No; only under certain conditions. It prevents too high a pressure for accumulating in the boiler when there is plenty of water; but when the water gets low the safety valve may only hasten the explosion by relieving some of the pressure and allowing superheated water to burst suddenly into steam, thus vastly expanding instantly.

Q. Should water be allowed to stand in the boiler when it is not in use?

A. It is better to draw it off and clean the boiler, to prevent rusting, formation of scale, hardening of sediment, etc., if boiler is to be left for any great length of time.

Q. What should you do if a grate bar breaks or falls out?

A. You should always have a spare grate bar on hand to put in its place; but if you have none you may fill the space by wedging in a stick of hard wood cut the right shape to fill the opening. Cover this wood with ashes before poking the fire over it, and it will last for several hours before it burns out. You will find it exceedingly difficult to keep up the fire with a big hole in the grate that will let cold air into the furnace and allow coal to drop down.

In case the grate is of the rocker type the opening may be filled by shaping a piece of flat iron, which can be set in without interfering with the rocking of the grate; or the opening may be filled with wood as before if the wood is covered well with ashes. Of course the use of wood will prevent the grate from rocking and the poker must be used to clean.

Q. Why should an engineer never start a boiler with a hot fire, and never let his fire get hotter than is needed to keep up steam?

A. Both will cause the sheets to warp and the flues to become leaky, because under high heat some parts of the boiler will expand more rapidly than others. For a similar reason, any sudden application of cold to a boiler, either cold water or cold air through the firebox door, will cause quicker contraction of certain parts than other parts, and this will ruin a boiler.

Q. How should you supply a boiler with water?

A. In a regular stream continually. Only by making the water pass regularly and gradually through the heater will you get the full effect of the heat from the exhaust steam. If a great deal of water is pumped into the boiler at one time, the exhaust steam will not be sufficient to heat it as it ought. Then if you have a full boiler and shut off the water supply, the exhaust steam in the heater is wasted, for it can do no work at all. Besides, it hurts the boiler to allow the temperature to change, as it will inevitably do if water is supplied irregularly.

WHATEVER YOU DO, NEVER ATTEMPT TO TIGHTEN A SCREW OR CALK A BOILER UNDER STEAM PRESSURE. IF ANYTHING IS LOOSE IT IS LIABLE TO BLOW OUT IN YOUR FACE WITH DISASTROUS CONSEQUENCES.

Q. If boiler flues become leaky, can an ordinary person tighten them?

A. Yes, if the work is done carefully. See full explanation previously given, p. 17. Great care should be taken not to expand the flues too much, for by so doing you are likely to loosen other flues and cause more leaks than you had in the first place. Small leaks inside a boiler are not particularly dangerous, but they should be remedied at the earliest possible moment, since they reduce the power of the boiler and put out the fire. Besides, they look bad for the engineer.

Q. How should flues be cleaned?

A. Some use a steam blower; but a better way is to scrape off the metal with one of the many patent scrapers, which just fill the flue, and when attached to a rod and worked back and forth a few times the whole length of the flue do admirable service.

Q. What harm will dirty flues do?

A. Two difficulties arise from dirty flues. If they become reduced in size the fire will not burn well. Then, the same amount of heat will do far less work because it is so much harder for it to get through the layer of soot and ashes, which are non-conductors.

Q. What would you do if the throttle broke?

A. Use reverse lever.

CHAPTER VIII.

OINTS FOR THE YOUNG ENGINEER.—(CONT.)

QUESTIONS AND ANSWERS.

THE ENGINE.

Q. What is the first thing to do with a new engine?

A. With some cotton waste or a soft rag saturated with benzine or turpentine clean off all the bright work; then clean every bearing, box and oil hole, using a force pump with air current first, if you have a pump, and then wiping the inside out clean with an oily rag, using a wire if necessary to make the work thorough. If you do not clean the working parts of the engine thus before setting it up, grit will get into the bearings and cause them to cut. Parts that have been put together need not be taken apart; but you should clean everything you can get at, especially the oil holes and other places that may receive dirt during transportation.

After the oil holes have been well cleaned, the oil cups may be wiped off and put in place, screwing them in with a wrench.

Q. What kind of oil should you use?

A. Cylinder oil only for the cylinder; lard oil for the bearings, and hard grease if your engine is provided with hard grease cup for the cross-head and crank. The only good substitute for cylinder oil is pure beef suet tried out. Merchantable tallow should never be used, as it contains acid.

Q. Can fittings be screwed on by hand only?

A. No; all fittings should be screwed up tight with a wrench.

Q. When all fittings are in place, what must be done before the engine can be started?

A. See that the grates in the firebox are in place and all right; then fill the boiler with clean water until it shows an inch to an inch and a half in the water gauge. Start your fire, and let it burn slowly until there is a pressure in the boiler of 10 or 15 lbs. Then you can turn on the blower to get up draft. In the meantime fill all the oil cups with oil; put grease on the gears; open and close all cocks to see that they work all right; turn your engine over a few times to see that it works all right; let a little steam into the cylinder with both cylinder cocks open—just enough to show at the cocks without moving the engine—and slowly turn the engine over, stopping it on the dead centers to see if the steam comes from only one of the cylinder cocks at a time, and that the proper one; reverse the engine and make the same test. Also see that the cylinder oiler is in place and ready for operation. See that the pump is all right and in place, with the valve in the feedpipe open and also the valve in the supply pipe.

By going over the engine in this way you will notice whether everything is tight and in working order, and whether you have failed to notice any part which you do not understand. If there is any part or fitting you do not understand, know all about it before you go ahead.

Having started your fire with dry wood, add fuel gradually, a little at a time, until you have a fire covering every part of the grate. Regulate the fire by the damper alone, never opening the firebox door even if the fire gets too hot.

Q. In what way should the engine be started?

A. When you have from 25 to 40 lbs. of pressure open the throttle valve a little, allowing the cylinder cocks to be open also. Some steam will condense at first in the cold cylinder, and this water must be allowed to drain off. See that the crank is not on a dead center, and put on just enough steam to start the engine. As soon as it gets warmed up, and only dry steam appears at the cocks, close the cylinder cocks, open the throttle gradually till it is wide open, and wait for the engine to work up to its full speed.

Q. How is the speed of the engine regulated??

A. By the governor, which is operated by a belt running to the main shaft. The governor is a delicate apparatus, and should be watched closely. It should move up and down freely on the stem, which should not leak steam. If it doesn't work steadily, you should stop the engine and adjust it, after watching it for a minute or two to see just where the difficulty lies.

Q. Are you likely to have any hot boxes?

A. There should be none if the bearings are all clean and well supplied with oil. However, in starting a new engine you should stop now and then and examine every bearing by laying your hand upon it. Remember the eccentric, the link pin, the cross-head, the crank pin. If there is any heat, loosen the boxes up a trifle, but only a very little at a time. If you notice any knocking or pounding, you have loosened too much, and should tighten again.

Q. What must you do in regard to water supply?

A. After the engine is started and you know it is all right, fill the tank on the engine and start the injector. It may take some patience to get the injector started, and you should carefully follow the directions previously given and those which apply especially to the type of injector used. Especially be sure that the cocks admitting the water through the feed pipe and into the boiler are open.

Q. Why are both a pump and an injector required on an engine?

A. The pump is most economical, because it permits the heat in the exhaust steam to be used to heat the feed water, while the injector heats the water by live steam. There should also be an injector, however, for use when the engine is not working, in order that the water in the boiler may be kept up with heated water. If a cross-head pump is used, of course, it will not operate when the engine is not running; and in case of an independent pump the heater will not heat the water when the engine is not running because there is little or no exhaust steam available. There is an independent pump (the Marsh pump) which heats the water before it goes into the boiler, and this may be used when the engine is shut down instead of the injector.

Q. What is the next thing to test?

A. The reversing mechanism. Throw the reverse lever back, and see if the engine will run equally well in the opposite direction. Repeat this a few times to make sure that the reverse is in good order.

Q. How is a traction engine set going upon the road?

A. Most traction engines now have the friction clutch. When the engine is going at full speed, take hold of the clutch lever and slowly bring the clutch against the band wheel. It will slip a little at first, gradually engaging the gears and moving the outfit. Hold the clutch lever in one hand, while with the other you operate the steering wheel. By keeping your hand on the clutch lever you may stop forward motion instantly if anything goes wrong. When the engine is once upon the road, the clutch lever may set in the notch provided for it, and the engine will go at full speed. You can then give your entire attention to steering.

Q. What should you do if the engine has no friction clutch?

A. Stop the engine, placing the reversing lever in the center notch. Then slide the spur pinion into the gear and open the throttle valve wide. You are now ready to control the engine by the reversing lever. Throw the lever forward a little, bringing it back, and so continue until you have got the engine started gradually. When well under way throw the reverse lever into the last notch, and give your attention to steering.

Q. How should you steer a traction engine?

A. In all cases the same man should handle the throttle and steer the engine. Skill in steering comes by practice, and about the only rule that can be given is to go slow, and under no circumstances jerk your engine about. Good steering depends a great deal on natural ability to judge distances by the eye and power by the feel. A good engineer must have a good eye, a good ear, and a good touch (if we may so speak). If either is wanting, success will be uncertain.

Q. How should an engine be handled on the road?

A. There will be no special difficulty in handling an engine on a straight, level piece of road, especially if the road is hard and without holes. But when you come to your first hill your troubles will begin.

Before ascending a hill, see that the water in the boiler does not stand more than two inches in the glass gauge. If there is too much water, as it is thrown to one end of the engine by the grade it is liable to get into the steam cylinder. If you have too much water, blow off a little from the bottom blow-off cock.

In descending a hill never stop your engine for a moment, since your crown sheet will be uncovered by reason of the water being thrown forward, and any cessation in the jolting of the engine which keeps the water flowing over the crown sheet will cause the fusible plug to blow out, making delay and expense.

Make it a point never to stop your engine except on the level.

Before descending a hill, shut off the steam at the throttle, and control the engine by the friction brake; or if there is no brake, do not quite close the throttle, but set the reverse lever in the center notch, or back far enough to control the speed. It is seldom necessary to use steam in going down hill, however, and if the throttle is closed even with no friction brake, the reverse may be used in such a way as to form an air brake in the cylinder.

Get down to the bottom of a hill as quickly as you can.

Before descending a hill it would be well to close your dampers and keep the firebox door closed tight all the time. Cover the fire with fresh fuel so as to keep the heat down.

The pump or injector must be kept at work, however, since as you have let the water down low, you must not let it fall any lower or you are likely to have trouble.

In ascending a hill, do just the reverse, namely: Keep your fire brisk and hot, with steam pressure ascending; and throw the reverse lever in the last notch, giving the engine all the steam you can, else you may get stuck. If you stop you are likely to overheat forward end of fire tubes. You are less liable to get stuck if you go slowly than if you go fast. Regulate speed by friction clutch.

CHAPTER IX.

POINTS FOR THE YOUNG ENGINEER—(CONT.)

MISCELLANEOUS.

Q. What is Foaming?

A. The word is used to describe the rising of water in large bubbles or foam. You will detect it by noticing that the water in the glass gauge rises and falls, or is foamy. It is due to sediment in the boiler, or grease and other impurities in the feed supply. Shaking up the boiler will start foaming sometimes; at other times it will start without apparent cause. In such cases it is due to the steam trying to get through a thick crust on the surface of the water.

Q. How may you prevent foaming?

A. It may be checked for a moment by turning off the throttle, so giving the water a chance to settle. It is generally prevented by frequently using the surface blow-off to clear away the scum. Of course the water must be kept as pure as possible, and especially should alkali water be avoided.

Q. What is priming?

A. Priming is not the same as foaming, though it is often caused by foaming. Priming is the carrying of water into the steam cylinder with the steam. It is caused by various things beside foaming, for it may be found when the boiler is quite clean. A sudden and very hot fire may start priming. Priming sometimes follows lowering of the steam pressure. Often it is due to lack of capacity in the boiler, especially lack of steam space, or lack of good circulation.

Q. How can you detect priming?

A. By the clicking sound it makes in the steam cylinder. The water in the gauge will also go up and down violently. There will also be a shower of water from the exhaust.

Q. What is the proper remedy for priming?

A. If it is due to lack of capacity in the boiler nothing can be done but get a new boiler. In other cases it may be remedied by carrying less water in the boiler when that can be done safely, by taking steam from a different point in the steam dome, or if there is no dome by using a long dry pipe with perforation at the end.

A larger steam pipe may help it; or it may be remedied by taking out the top row of flues.

Leaky cylinder rings or a leaky valve may also have something to do with it. In all cases these should be made steam tight. If the exhaust nozzle is choked up with grease or sediment, clean it out.

A traction engine with small steam ports would prime quickly under forced speed.

Q. How would you bank your fires?

A. Push the fire as far to the back of the firebox as possible and cover it over with very fine coal or with dry ashes. As large a portion as possible of the grate should be left open, so that the air may pass over the fire. Close the damper tight. By banking your fires at night you keep the boiler warm and can get up steam more quickly in the morning.

Q. When water is left in the boiler with banked fire in cold weather, what precautions ought to be taken?

A. The cocks in the glass water gauge should be closed and the drain cock at the bottom opened, for fear the water in the exposed gauge should freeze. Likewise all drain cocks in steam cylinder and pump should be opened.

Q. How should a traction engine be prepared for laying up during the winter?

A. First, the outside of the boiler and engine should be thoroughly cleaned, seeing that all gummy oil or grease is removed. Then give the outside of the boiler and smokestack a coat of asphalt paint, or a coat of lampblack and linseed oil, or at any rate a doping of grease.

The outside of the boiler should be cleaned while it is hot, so that grease, etc., may be easily removed while soft.

After the outside has been attended to, blow out the water at low pressure and thoroughly clean the inside in the usual way, taking out the handhole and manhole plates, and scraping off all scale and sediment.

After the boiler has been cleaned on the inside, fill it nearly full of water, and pour upon the top a bucket of black oil. Then let the water out through the blow-off at the bottom. As the water goes down it will have a coating of oil down the sides of the boiler.

All the brass fittings should be removed, including gauge cocks, check valves, safety valve, etc. Disconnect all pipes that may contain water, to be sure none remains in any of them. Open all stuffing boxes and take out packing, for the packing will cause the parts they surround to rust.

Finally, clean out the inside of the firebox and the fire flues, and give the ash-pan a good coat of paint all over, inside as well as out.

The inside of the cylinder should be well greased, which can be done by removing the cylinder head.

See that the top of the smoke stack is covered to keep out the weather.

All brass fittings should be carefully packed and put away in a dry place.

A little attention to the engine when you put it up will save twice as much time when you take it out next season, and besides save many dollars of value in the life of the engine.

Q. How should belting be cared for?

A. First, keep belts free from dust and dirt.

Never overload belts.

Do not let oil or grease drip upon them.

Never put any sticky or pasty grease on a belt.

Never allow any animal oil or grease to touch a rubber belt, since it will destroy the life of the rubber.

The grain or hair side should run next the pulley, as it holds better and is not so likely to slip.

Rubber belts will be greatly improved if they are covered with a mixture of black lead and litharge, equal parts, mixed with boiled oil, and just enough japan to dry them quickly. This mixture will do to put on places that peel.

Q. What is the proper way to lace a belt?

A. First, square the ends with a proper square, cutting them off to a nicety. Begin to lace in the middle, and do not cross the laces on the pulley side. On that side the lacings should run straight with the length of the belt.

The holes in the belt should be punched if possible with an oval punch, the long diameter coinciding with the length of the belt. Make two rows of holes in each end of the belt, so that the holes in each row will alternate with those in preceding row, making a zigzag. Four holes will be required for a three-inch belt in each end, two holes in each row; in a six-inch belt, place seven holes in each end, four in the row nearest the end.

To find the length of a belt when the exact length cannot be measured conveniently, measure a straight line from the center of one pulley to the center of the other. Add together half the diameter of each pulley, and multiply that by 3¼ (3.1416). The result added to twice the distance between the centers will give the total length of the belt.

A belt will work best if it is allowed to sag just a trifle.

The seam side of a rubber belt should be placed outward, or away from the pulley.

If such a belt slips, coat the inside with boiled linseed oil or soap.

Cotton belting may be preserved by painting the pulley side while running with common paint, afterward applying soft oil or grease.

If a belt slips apply a little oil or soap to the pulley side.

Q. How does the capacity of belts vary?

A. In proportion to width and also to the speed. Double the width and you double the capacity; also, within a certain limit, double the speed and you double the capacity. A belt should not be run over 5,000 feet per minute. One four-inch belt will have the same capacity as two two-inch belts.

Q. How are piston rods and valve rods packed so that the steam cannot escape around them?

A. By packing placed in stuffing-boxes. The stuffing is of some material that has a certain amount of elasticity, such as lamp wick, hemp, soap stone, etc., and certain patent preparations. The packing is held in place by a gland, as it is called, which acts to tighten the packing as the cap of the stuffing-box is screwed up.

Q. How would you repack a stuffing-box?

A. First remove the cap and the gland, and with a proper tool take out all the old packing. Do not use any rough instrument like a file, which is liable to scratch the rod, for any injury to the smooth surface of the rod will make it leak steam or work hard.

If patent packing is used, cut off a sufficient number of lengths to make the required rings. They should be exactly the right length to go around inside the stuffing-box. If too long, they cannot be screwed up tight, as the ends will press together and cause irregularities. If too short, the ends will not meet and will leak steam. Cut the ends diagonally so that they will make a lap joint instead of a square one. When the stuffing-box has been filled, place the gland in position and screw up tight. Afterwards loosen the nuts a trifle, as the steam will cause the packing to expand, usually. The stuffing-box should be just as loose as it can be and not allow leakage of steam. If steam leaks, screw up the box a little tighter. If it still leaks, do not screw up as tight as you possibly can, but repack the box. If the stuffing-box is too tight, either for the piston rod or valve steam, it will cause the engine to work hard, and may groove the rods and spoil them.

If hemp packing is used, pull the fibres out straight and free, getting rid of all knots and lumps. Twist together a few of the fibres, making three cords, and braid these three cords together and soak them with oil or grease, wind around the rod till stuffing-box is sufficiently full, replace the gland, and screw up as before.

Stuffing-box for water piston of pump may be packed as described above, but little oil or grease will be needed.

Never pack the stuffing-box too tight, or you may flute the rod and spoil it.

Always keep the packing in a clean place, well covered up, never allowing any dust to get into it, for the dust or grit is liable to cut the rod.

CHAPTER X.

ECONOMY IN RUNNING A FARM ENGINE.

It is something to be able to run a farm engine and keep out of trouble. It is even a great deal if everything runs smoothly day in and day out, if the engine looks clean, and you can always develop the amount of power you need. You must be able to do this before you can give the fine points of engineering much consideration.

When you come to the point where you are always able to keep out of trouble, you are probably ready to learn how you can make your engine do more work on less fuel than it does at present. In that direction the best of us have an infinite amount to learn. It is a fact that in an ordinary farm engine only about 4 per cent of the coal energy is actually saved and used for work; the rest is lost, partly in the boiler, more largely in the engine. So we see what a splendid chance there is to save.

If we are asked where all the lost energy goes to, we might reply in a general sort of way, a good deal goes up the smokestack in smoke or unused fuel; some is radiated from the boiler in the form of heat and is lost without producing any effect on the steam within the boiler; some is lost in the cooling of the steam as it passes to the steam cylinder; some is lost in the cooling of the cylinder itself after each stroke; some is lost through the pressure on the back of the steam valve, causing a friction that requires a good deal of energy in the engine to overcome; some is lost in friction in the bearings, stuffing-boxes, etc. At each of these points economy may be practiced if the engineer knows how to do it. We offer a few suggestions.

THEORY OF STEAM POWER.

As economy is a scientific question, we cannot study it intelligently without knowing something of the theory of heat, steam and the transmission of power. There will be nothing technical in the following pages; and as soon as the theory is explained in simple language, any intelligent person will know for himself just what he ought to do in any given case.

First, let us define or describe heat according to the scientific theory. Scientists suppose that all matter is made up of small particles called molecules, so small that they have never been seen. Each molecule is made up of still smaller particles called atoms. There is nothing smaller than an atom, and there are only about sixty-five different kinds of atoms, which are called elements; or rather, any substance made up of only one kind of atom is called an element. Thus iron is an element, and so is zinc, hydrogen, oxygen, etc. But a substance like water is not an element, but a compound, since its molecules are made up of an atom of oxygen united with two atoms of hydrogen. Wood is made up of many different kinds of atoms united in various ways. Air is not a compound, but a mixture of oxygen, nitrogen and a few other substances in small quantities.

The reason why air is a mixture and not a compound is an interesting one, and brings us to our next point. In order to form a compound, two different kinds of atoms must have an attraction for each other. There is no attraction between oxygen and nitrogen; but there is great attraction between oxygen and carbon, and when they get a chance they rush together like long separated overs. Anthracite coal is almost pure carbon. So is charcoal. Soft coal consists of carbon with which various other things are united, one of them being hydrogen. This is interesting and important, because it accounts for a curious thing in firing up boilers with soft coal. We have already said that water is oxygen united with hydrogen. When soft coal burns, not only does the carbon unite with oxygen, but the hydrogen unites with oxygen and forms water, or steam. While the boilers are cold they will condense the water or steam in the smoke, just as a cold plate in a steamy room will condense water from the steamy air, so sweating.

Now the scientists suppose that two or three atoms stick together by reason of their attraction for each other and form molecules. These molecules in turn stick together and form liquids and solids. The tighter they stick, the harder the substance. At the same time, these molecules are more or less loose, and are constantly moving back and forth. In a solid like iron they move very little; but a current of electricity through iron makes the molecules move in a peculiar way. In a liquid like water, the molecules cling together very loosely, and may easily be pulled apart. In any gas, like air or steam, the molecules are entirely disconnected, and are constantly trying to get farther apart.

Heat, says the scientist, is nothing more or less than the movement of the molecules back and forth. Heat up a piece of iron in a hot furnace, and the molecules keep getting further and further apart, and the iron gets softer and softer, till it becomes a liquid. If we take some liquid like water and heat it, the molecules get farther and farther apart, till the water boils, as we say, or turns into steam. As steam the molecules have broken apart entirely, and are beating back and forth so rapidly that they have a tendency to push each other farther and farther apart. This pushing tendency is the cause of steam pressure. It also explains why steam has an expansive power.

Heat, then, is the movement of the molecules back and forth. There are three fixed ranges in which they move; the small range makes a solid; the next range makes a liquid; the third range makes a gas, such as steam. These three states of matter as affected by heat are very sharp and definite. The point at which a solid turns to a liquid is called the melting point. The melting point of ice is 32° Fahr. The point at which it turns to a gas is called the boiling point. With water that is 212° Fahr. The general tendency of heat is to push apart, or expand; and when the heat is taken away the substances contract.

Let us consider our steam boiler. We saw that some different kinds of atoms have a strong tendency to rush together; for example, oxygen and carbon. The air is full of oxygen, and coal and wood are full of carbon. When they are raised to a certain temperature, and the molecules get loose enough so that they can tear themselves away from whatever they are attached to, they rush together with terrible force, which sets all surrounding molecules to vibrating faster than ever. This means that heat is given out.

Another important thing is that when a solid changes to a liquid, or a liquid to a gas, it must take up a certain amount of heat to keep the molecules always just so far apart. That heat is said to become latent, for it will not show in a thermometer, it will not cause anything to expand, nor will it do any work. It merely serves to hold the molecules just so far apart.

HOW ENERGY IS LOST.

We may now see some of the ways in which energy is lost. First, the air which goes into the firebox consists of nitrogen as well as oxygen. That nitrogen is only in the way, and takes heat from the fire, which it carries out at the smokestack.

Again, if the air cannot get through the bed of coals easily enough, or there is not enough of it so that every atom of carbon, etc., will find the right number of atoms of oxygen, some of the atoms of carbon will be torn off and united with oxygen, and the other atoms of carbon, left without any oxygen to unite with, will go floating out at the smokestack as black smoke. Also, the carbon and the oxygen cannot unite except at a certain temperature, and when fresh fuel is thrown on the fire it is cold, and a good many atoms of carbon after being loosened up, get cooled off again before they have a chance to find an atom of oxygen, and so they, too, go floating off and are lost.

If the smoke could be heated up, and there were enough oxygen mixed with it, the loose carbon would still burn and produce heat, and there would be an economy of fuel. This has given rise to smoke consumers, and arranging two boilers, so that when one is being fired the heat from the other will catch the loose carbon before it gets away and burn it up.

So we have these points:

1. Enough oxygen or air must get into a furnace so

that every atom of carbon will have its atom of oxygen. This means that you must have a good draft and that the air must have a chance to get through the coal or other fuel.

2. The fuel must be kept hot enough all the time so that the carbon and oxygen can unite. Throwing on too much cold fuel at one time will lower the heat beyond the economical point and cause loss in thick smoke.

3. If the smoke can pass over a hot bed of coals, or through a hot chamber, the carbon in it may still be burned. This suggests putting fuel at the front of the firebox, a little at a time, so that its smoke will have to pass over a hot bed of coals and the waste carbon will be burned. When the fresh fuel gets heated up, it may be pushed farther back.

From a practical point of view these points mean, No dead plates in a furnace to keep the air from going through coal or wood; a thin fire so the air can get through easily; place the fresh fuel where its smoke will have a chance to be burned; and do not cool off the furnace by putting on much fresh fuel at a time.

(Later we will give more hints on firing.)

HOW HEAT IS DISTRIBUTED.

We have described heat as the movement of molecules back and forth at a high rate of speed. If these heated molecules beat against a solid like iron, its molecules are set in motion, one knocks the next, and so on, just as you push one man in a crowd, he pushes the next, and so on till the push comes out on the other side. So heat passes through iron and appears on the other side. This is called "conduction."

All space is supposed to be filled with a substance in which heat, light, etc., may be transmitted, called the ether. When the molecules of a sheet of iron are heated, or set vibrating, they transmit the vibration through the air, or ether. This is called "radiation." Heat is "conducted" through solid and liquid substances, and "radiated" through gases.

Now some substances conduct heat readily, and some do so with the greatest difficulty. Iron is a good conductor; carbon, or soot on the flues of a boiler, and lime or scale on the inside of a boiler, are very poor conductors. So the heat will go through the iron and steel to the water in a boiler quickly and easily, and a large per cent of the heat of the furnace will get to the water in a boiler. When a boiler is old and is clogged with soot and coated with lime, the heat cannot get through easily, and goes off in the smokestack. The air coming out of the smokestack will be much hotter; and that extra heat is lost.

Iron is a good radiator, too. So if the outer shell of a boiler is exposed to the air, a great deal of heat will run off into space and be lost. Here, then, is where you need a non-conductor, as it is called, such as lime, wood, or the like.

Economy says, cover the outside of a boiler shell with a non-conductor. This may be brickwork in a set boiler; in a traction boiler it means a jacket of wood, plaster, hair, or the like. The steam pipe, if it passes through outer air, should be covered with felt; and the steam cylinder ought to have its jacket, too.

At the same time all soot and all scale should be scrupulously cleaned away.

PROPERTIES OF STEAM.

As we have already seen, steam is a gas. It is slightly blue in color, just as the water in the ocean is blue, or the air in the sky.

We must distinguish between steam and vapor. Vapor is small particles of water hanging in the air. They seem to stick to the molecules composing the air, or hang there in minute drops. Water hanging in the air is, of course, water still. Its molecules do not have the movement that the molecules of a true gas do, such as steam is. Steam, moreover, has absorbed latent heat, and has expansive force; but vapor has no latent heat, and no expansive force. So vapor is dead and lifeless, while steam is live and full of energy to do work.

When vapor gets mixed with steam it is only in the way; it is a sort of dead weight that must be carried;

and the steam power is diminished by having vapor mixed with it.

Now all steam as it bubbles up through water in boiling takes up with it a certain amount of vapor. Such steam is called "wet" steam. When the vapor is no longer in it, the steam is called "dry" steam. It is dry steam that does the best work, and that every engineer wants to get.

While water will be taken up to great heights in the air and form clouds, in steam it will not rise very much, and at a certain height above the level of the water in a boiler the steam will be much drier than near the surface. For this reason steam domes have been devised, so that the steam may be taken out at a point as high as possible above the water in the boiler, and so be as dry as possible. Also "dry tubes" have been devised, which let the steam pass through many small holes that serve to keep back the water to a certain extent.

However, there will be more or less moisture in all steam until it has been superheated, as it is called. This may be done by passing it through the hot part of the furnace, where the added heat will turn all the moisture in the steam into steam, and we shall have perfectly dry steam.

The moment, however, that steam goes through a cold pipe, or one cooled by radiation, or goes into a cold cylinder, or a cylinder cooled by radiation, some of the steam will turn to water, or condense, as it is called. So we have the same trouble again.

Much moisture passing into the cylinder with the steam is called "priming." In that case the dead weight of water has become so great as to kill a great part of the steam power.

HOW TO USE THE EXPANSIVE POWER OF STEAM.

We have said that the molecules in steam are always trying to get farther and farther apart. If they are free in the air, they will soon scatter; but if they are confined in a boiler or cylinder they merely push out in every direction, forming "pressure."

When steam is let into the cylinder it has the whole accumulated pressure in the boiler behind it, and of course that exerts a strong push on the piston. Shut off the boiler pressure and the steam in the cylinder will still have its own natural tendency to expand. As the space in the cylinder grows larger with the movement of the piston from end to end, the expansive power of the steam becomes less and less, of course. However, every little helps, and the push this lessened expansive force exerts on the piston is so much energy saved. If the full boiler pressure is kept on the piston the whole length of the stroke, and then the exhaust port is immediately opened, all this expansive energy of the steam is lost. It escapes through the exhaust nozzle into the smokestack and is gone. Possibly it cannot get out quickly enough, and causes back pressure on the cylinder when the piston begins its return stroke, so reducing the power of the engine.

To save this the skilled engineer "notches up" his reverse lever, as they say. The reverse lever controls the valve travel. When the lever is in the last notch the valve has its full travel. When the lever is in the center notch the valve has no travel at all, and no steam can get into the cylinder; on the other side the lever allows the valve to travel gradually more and more in the opposite direction, so reversing the engine.

As the change from one direction to the other direction is, of course, gradual, the valve movement is shortened by degrees, and lets steam into the cylinder for a correspondingly less time. At its full travel it perhaps lets steam into the cylinder for three-quarters of its stroke. For the last quarter the work is done by the expansive power of the steam.

Set the lever in the half notch, and the travel of the valve is so altered that steam can get into the cylinder only during half the stroke of the piston, the work during the rest of the stroke being done by the expansive force of the steam.

Set the lever in the notch next to the middle notch, or the quarter notch, and steam will get into the cylinder only during a quarter of the stroke of the piston, the work being done during three-quarters of the stroke by the expansive force of the steam.

Obviously the more the steam is expanded the less work it can do. But when it escapes at the exhaust there will be very little pressure to be carried away and lost.

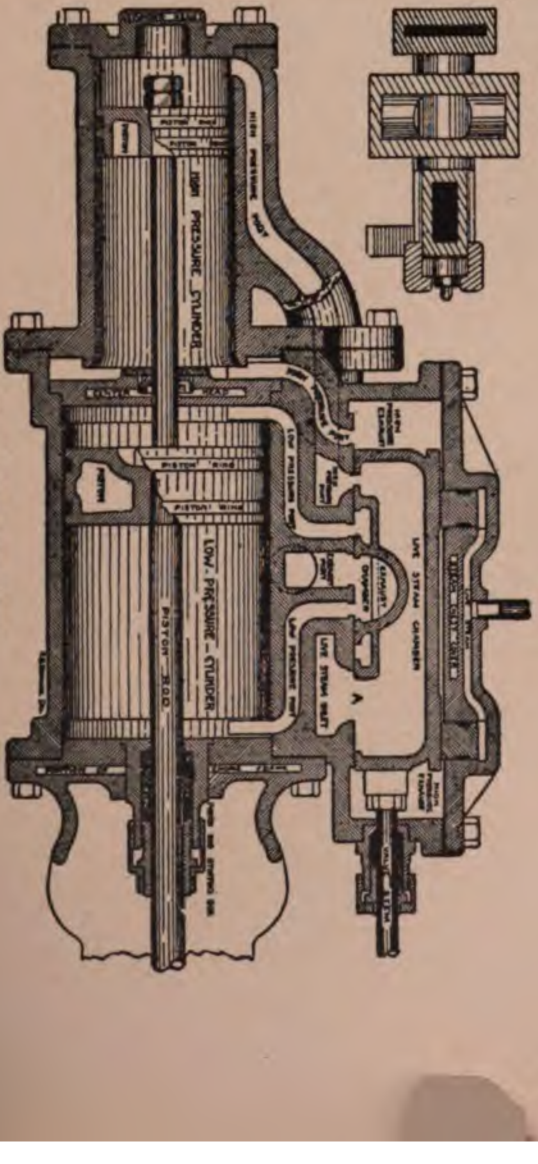
Therefore when the load on his engine is light the economical engineer will "notch up" his engine with the reverse lever, and will use up correspondingly less steam and save correspondingly more fuel. When the load is unusually heavy, however, he will have to use the full power of the pressure in the boiler, and the waste cannot be helped.

THE COMPOUND ENGINE.

The compound engine is an arrangement of steam cylinders to save the expansive power of steam at all times by letting the steam from one cylinder where it is at high pressure into another after it exhausts from the first, in this second cylinder doing more work purely by the expansive power of the steam.

The illustration shows a sectional view of a compound engine having two cylinders, one high pressure and one low. The low pressure cylinder is much larger than the high pressure. There is a single plate between them called the center head, and the same piston rod is fitted with two pistons, one for each cylinder. The steam chest does not receive steam from the boiler, but from the exhaust of the high pressure cylinder. The steam from the boiler goes into a chamber in the double valve, from which it passes to the ports of the high pressure cylinder. At the return stroke the exhaust steam escapes into the steam chest, and from there it passes into the low pressure cylinder. There may be one valve riding on the back of another; but the simplest form of compound engine is built with a single double valve, which opens and closes the ports for both cylinders at one movement.

Theoretically the compound engine should effect a genuine economy. In practice there are many things to operate against this. Of course if the steam pressure is low to start with, the amount of pressure lost in the exhaust will be small. But if it is very high, the saving



WOOLF TANDEM CYLINDER.

in the low pressure cylinder will be relatively large. If the work can be done just as well with a low pressure, it would be a practical waste to keep the pressure abnormally high in order to make the most of the compound engine.

An engine must be a certain size before the saving of a compound cylinder will be appreciable. In these days nearly all very large engines are compound, while small engines are simple.

Another consideration to be taken into account is that a compound is more complicated and so harder to manage; and when any unfavorable condition causes loss it causes proportionately more loss on a compound than on a simple engine. For these and other reasons compound engines have been used less for traction purposes than simple engines have. It is probable that a skilled and thoroughly competent engineer, who would manage his engine in a scientific manner, would get more out of a compound than out of a simple; and this would be especially true in regions where fuel is high. If fuel is cheap and the engineer unskilled, a compound engine would be a poor economizer.

FRICTION.

We have seen that the molecules of water have a tendency to stick in the steam as vapor or moisture. All molecules that are brought into close contact have more or less tendency to stick together, and this is called friction. The steam as it passes along the steam pipe is checked to a certain extent by the friction on the sides of the pipe. Friction causes heat, and it means that the heat caused has been taken from some source of energy. The friction of the steam diminishes the energy of the steam.

So, too, the fly wheel moving against the air suffers friction with the air, besides having to drive particles of air out of its path. All the moving parts of an engine where one metal moves on another suffer friction, since where the metals are pressed very tightly together they have more tendency to stick than when not pressed so tightly. When iron is pressed too tightly, as under the blows of a hammer in a soft state, it actually welds together solidly.

There is a great deal of friction in the steam cylinder, since the packing rings must press hard against the walls of the cylinder to prevent the steam from getting through. There is a great deal of friction between the D valve and its seat, because of the high steam pressure on the back of the valve. There is friction in the stuffing boxes both of the valve and the piston. There is friction at all the bearings.

There are various ways in which friction may be reduced. The most obvious is to adjust all parts so nicely that they will bind as little as possible. The stuffing-boxes will be no tighter than is necessary to prevent leaking of steam; and so with the piston rings. Journal boxes will be tight enough to prevent pounding, but no tighter. To obtain just the right adjustment requires great patience and the keen powers of observation and judgment.

The makers of engines try to reduce friction as much as possible by using anti-friction metals in the boxes. Iron and steel have to be used in shafts, gears, etc., because of the strength that they possess; but there are some metals that stick to each other and to iron and steel much less than iron or steel stick to each other when pressed close together. These metals are more or less soft; but they may be used in boxes and journal bearings. They are called anti-friction metals. The hardest for practical purposes is brass, and brass is used where there is much wear. Where there is less wear various alloys of copper, tin, zinc, etc., may be used in the boxes. One of these is babbit metal, which is often used in the main journal box.

All these anti-friction metals wear out rapidly, and they must be put in so that they can be adjusted or renewed easily.

But the great anti-friction agent is oil.

Oil is peculiar in that while the molecules seem to stick tightly together and to a metal like iron or steel, they roll around upon each other with the utmost ease. An ideal lubricator is one that sticks so tight to the journal that it forms a sort of cushion all around it, and prevents any of its molecules coming into contact with the molecules of the metal box. All the friction then takes place between the different molecules of oil, and this friction is a minimum.

The same principle has been applied to mechanics in the ball bearing. A number of little balls roll around between the journal and its box, preventing the two metals from coming into contact with each other; while the balls, being spheres, touch each other only at a single point, and the total space at which sticking can occur is reduced to a minimum.

As is well known, there is great difference in oils. Some evaporate, like gasoline and kerosene, and so disappear quickly. Others do not stick tightly to the journal, so are easily forced out of place, and the metals are allowed to come together. What is wanted, then, is a heavy, sticky oil that will not get hard, but will always form a good cushion between bearings.

Steam cylinders cannot be oiled directly, but the oil must be carried to the steam chest and cylinder in the steam. A good cylinder oil must be able to stand a high temperature. While it is diffused easily in the steam, it must stick tightly to the walls of the steam cylinder and to the valve seat, and keep them lubricated. Once it is stuck to the metal, the heat of the steam should not evaporate it and carry it away.

Again, a cylinder oil should not have any acid in it which would have a tendency to corrode the metal. Nearly all animal fats do have some such acid. So tallow and the like should not be placed where they can corrode iron or steel. Lard and suet alone are suitable for use on an engine.

When it comes to lubricating traction gears, other problems appear. A heavy grease will stick to the gears and prevent them from cutting; but it will stick equally to all sand and grit that may come along, and that, working between the cogs, may cut them badly. So some engineers recommend the use on gears of an oil that does not gather so much dirt.

The friction of the valve on its seat due to the pressure of the steam on its back has given rise to many inventions for counteracting it. The most obvious of these is what is called "the balanced valve." In the compound engine, where the steam pressure is obtained upon both sides of the valve, it rides much more lightly on its seat—so lightly, indeed, that when steam pressure is low, as in going down hill or operating under a light load, plunger pistons must be used to keep the valve down tight on its seat.

The poppet valves were devised to obviate the undue friction of the D valve; but the same loss of energy is to a certain extent transferred, and the practical saving is not always equal to the theoretical. On large stationary engines rotary valves and other forms, such as are used on the Corliss engine, have come into common use; but they are too complicated for a farm engine, which must be as simple as possible, with least possible liability of getting out of order.

CHAPTER XI.

ECONOMY IN RUNNING A FARM ENGINE.—(CONT.)

PRACTICAL POINTS.

The first practical point in the direction of farm engine economy is to note that the best work can be done only when every part of the engine and boiler are in due proportion. If the power is in excess of the work to be done there is loss; if the grate surface is too large cold air gets through the fuel and prevents complete combustion, and if the grate surface is too small, not enough air gets in; if the steaming power of the boiler is too large, heat is radiated away that otherwise could be saved, for every foot of exposed area in the boiler is a source of loss; if the steaming power of the boiler is too low for the work to be done, it requires extra fuel to force the boiler to do its work, and any forcing means comparativelv large loss or waste. It will be seen that not only must the engine and boiler be built with the proper proportions, but they must be bought with a nice sense of proportion to the work expected of them. This requires excellent judgment and some experience in measuring work in horsepowers.

GRATE SURFACE AND FUEL.

The grate surface in a firebox should be not less than two-thirds of a square foot per horsepower, for average size traction engines. If the horsepower of an engine is small, proportionately more grate surface will be needed; if it is large, the grate surface may be proportionately much smaller. An engine boiler 7x8x200 rev., with 100 lbs. pressure, should have a great surface not less than six square feet, and seven would be better. In a traction engine there is always a tendency to make the grate surface as small as possible, so that the engine will not be cumbersome.

Another reason why the grate surface should be sufficiently large is that forced draft is a bad thing, since it has a tendency to carry the products of combustion and hot gases through the smokestack and out into space before they have time to complete combustion and especially before the heat of the gases has time to be absorbed by the boiler surface. A large grate surface, then, with a moderate draft, is the most economical.

The draft depends on other things, however. If a great deal of fine fuel is thrown on a fire, the air must be forced through, because it cannot get through in the natural way. This results in waste. So a fire should be as open as possible. Coal should be "thin" on the grates; wood should be thrown in so that there will be plenty of air spaces; straw should be fed in just so that it will burn up completely as it goes in. Moderate size coal is better than small or fine. Dust in coal checks the draft. A good engineer will choose his fuel and handle his fire so that he can get along with as little forced draft as possible.

In a straw burning engine a good circulation of air can be obtained, if the draft door is just below the straw funnel, by extending the funnel into the furnace six inches or so. This keeps the straw from clogging up the place where the air enters and enables it to get at the fuel so much more freely that the combustion is much more complete.

We have already suggested that in firing with coal, the fresh fuel be deposited in front, so that the smoke will have to pass over live coals and so the combustion will be more complete. Then when the coal is well lighted it can be poked back over the other portions of the grate. This method has another advantage, in that the first heating is usually sufficient to separate the pure coal from the mineral substances which form clinkers, and most of the clinkers will be deposited at that one point in the grate. Here they can easily be lifted out, and will not seriously interfere with the burning of the coal as they would if scattered all over the grate. Clinkers in front can easily be taken out by hooking the poker over them toward the back of the firebox and pulling them up and to the front.

They often come out as one big mass which can be easily lifted out.

The best time to clean the grate is when there is a good brisk fire. Then it will not cause steam to go down. Stirring a fire does little good. For one thing, it breaks up the clinkers and allows them to run down on the grate bars when they stick and finally warp the bars. If the fire is not stirred the clinkers can be lifted out in large masses. Stirring a fire also creates a tendency to choke up or coke, and interferes with the even and regular combustion of the coal at all points.

The highest heat that can be produced is a yellow heat. When there is a good yellow heat, forced draft will only carry off the heat and cause waste. It will not cause still more rapid combustion. When the heat is merely red, increased draft will raise the temperature. Combustion is not complete until the flame shows yellow. However, if the draft is slight and time is given, red heat will be nearly as effective, but it will not carry the heated gases over so large a part of the heating surface of the boiler. With a very large grate surface, red heat will do very well. Certainly it will be better than a forced draft, or an effort at heating beyond the yellow point.

BOILER HEATING SURFACE.

The heat of the furnace does its work only as the heated gases touch the boiler surface. The iron conducts the heat through to the water, which is raised to the boiling point and turned into steam.

Now the amount of heat that the boiler will take up is directly in proportion to the amount of exposed surface and to the time of exposure. If the boiler heating surface is small, and the draft is forced so that the gases pass through rapidly, they do not have a chance to communicate much heat.

Also if the heating surface is too large, so that it cannot all be utilized, the part not used becomes a radiating surface, and the efficiency of the boiler is impaired.

Practice has shown that the amount of heating surface practically required by a boiler is 12 to 15 square feet per horsepower. In reckoning heating surface, all area which the heated gases touch is calculated.

Another point in regard to heating surface in the production of steam is this, that only such surface as is exposed to a heat equal to turning the water into steam is effective. If there is a pressure of 150 lbs. the temperature at which the water would turn to steam would be 357 degrees, and any gases whose temperature was below 357 degrees would have no effect on the heating surface except to prevent radiation. Thus in a return flue boiler the heated gases become cooled often to such an extent before they pass out at the smokestack that they do not help the generation of steam. Yet a heat just below 357 degrees would turn water into steam under 149 lbs. pressure. Though it has work in it, the heat is lost.

Another practical point as to economy in large heating surface is that it costs money to make, and is cumbersome to move about. It may cost more to move a traction engine with large boiler from place to place than the saving in fuel would amount to. So the kind of roads and the cost of fuel must be taken into account and nicely balanced.

However, it may be said that a boiler with certain outside dimensions that will generate 20 horsepower will be more economical than one of the same size that will generate only 10 horsepower. In selecting an engine, the higher the horsepower for the given dimensions, the more economical of both fuel and water.

The value of heating surface also depends on the material through which the heat must penetrate, and the rapidity with which the heat will pass. We have already pointed out that soot and lime scale permit heat to pass but slowly and if they are allowed to accumulate will greatly reduce the steaming power of a boiler for a given consumption of fuel. Another point is that the thinner the iron or steel, the better will the heat get through even that. So it follows that flues, being thinner, are better conductors than the sides of the firebox. Long flues are better than short ones in that the long ones allow less soot, etc., to accumulate than the short ones do, and afford more time for the boiler to absorb the heat of the gases.

Again, we have stated that heating surface is valuable only as it is exposed to the gases at a sufficiently high temperature. Some boilers have a tendency to draw the hot gases most rapidly through the upper flues, while the lower flues do not get their proportion of the heat. This results in a loss, for the heat to give its full benefit should be equally distributed.

To prevent the heat being drawn too rapidly through upper flues, a baffle plate may be placed in the smoke box just above the upper flues, thus preventing them from getting so much of the draft.

Again, if the exhaust nozzle is too low down, the draft through the lower flues may be greater than through the upper. This is remedied by putting a piece of pipe on the exhaust to raise it higher in the smokestack.

EXPANSION AND CONDENSATION.

We have already pointed out that economy results if we hook up the reverse lever so that the expansive force of the steam has an opportunity to work during half or three-quarters of the stroke.

One difficulty arising from this method is that the walls of the cylinder cool more rapidly when not under the full boiler pressure. Condensation in the cylinder is a practical difficulty which should be met and overcome as far as possible.

High speed gives some advantage. A judicious use of cushion helps condensation somewhat also, because when any gas like steam or air is compressed, it gives off heat, and this heat in the cushion will keep up the temperature of the cylinder. This cannot be carried very far, however, for the back pressure of cushion will reduce the energy of the engine movement.

LEAD AND CLEARANCE.

Too much clearance will detract from the power of an engine, as there is just so much more waste space to be filled with hot steam. Too little clearance will cause pounding.

Likewise there will be loss of power in an engine if the lead is too great or too little. The proper amount of lead differs with conditions. A high speed engine requires more than a low speed, and if an engine is adjusted for a certain speed, it should be kept uniformly at that speed, as variation causes loss. The more clearance an engine has the more lead it needs. Also the quicker the valve motion, the less lead required. Sometimes when a large engine is pulling only a light load and there is no chance to shorten the cut-off, a turn of the eccentric disk for a trifle more lead will effect some economy.

Cut-off should be as sharp as possible. A slow cut-off in reducing pressure before cut-off is complete, causes a loss of power in the engine.

THE EXHAUST.

If the exhaust from the cylinder does not begin before the piston begins its return stroke, there will be back pressure due to the slowness with which the valve opens. The exhaust should be earlier in proportion to the slowness of the valve motion, and also in proportion to the speed of the engine, since the higher the speed the less time there is for the steam to get out. It follows that an engine whose exhaust is arranged for a low speed cannot be run at a high speed without causing loss from back pressure.

In using steam expansively the relative proportion between the back pressure and the force of the steam is of course greater. So in using steam expansively the back pressure must be at a minimum, and this is especially true in the compound engine. So many things affect this, that it becomes one of the reasons why it is hard to use a compound engine with as great economy as theory would indicate.

Another thing, the smallness of the exhaust nozzle in the smokestack affects the back pressure. The smaller the nozzle, the greater the draft a given amount of steam will create; but the more back pressure there will be, due to the inability of the exhaust steam to get out easily. So the exhaust nozzle should be as large as circumstances will permit. It is a favorite trick with engineers testing the pulling power of their engines to remove the exhaust nozzle entirely for a few minutes when the fire is up. The back pressure saved will at once show in the pulling power of the engine, and every one will be surprised. Of course the fire couldn't be kept going long without the nozzle on. We have already pointed out that a natural draft is better than a forced one. Here is another reason for it.

LEAKS.

Leaks always cause a waste of power. They may usually be seen when about the boiler; but leaks in the piston and valve will often go unnoticed.

It is to be observed that if a valve does not travel a short distance beyond the end of its seat, it will wear the part it does travel on, while the remaining part will not wear and will become a shoulder. Such a shoulder will nearly always cause a leak in the valve, and besides will add the friction, and otherwise destroy the economy of the engine.

Likewise the piston will wear part of the cylinder and leave a shoulder at either end if it does not pass entirely beyond the steam-tight portion of the inside of the cylinder. That it may always do this and yet leave sufficient clearance, the counterbore has been devised. All good engines are bored larger at each end so that the piston will pass beyond the steam-tight portion a trifle at the end of each stroke. Of course it must not pass far enough to allow any steam to get through.

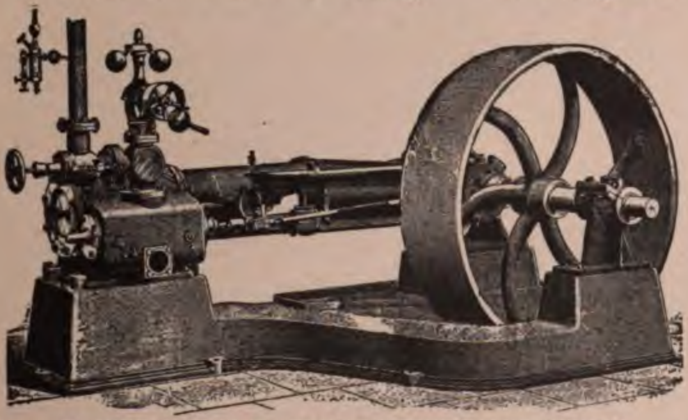
Self-setting piston rings are now generally used. They are kept in place by their own tension. There will always be a little leakage at the lap. The best lap is probably a broken joint rather than a diagonal one. Moreover, as the rings wear they will have a tendency to get loose unless they are thickest at a point just opposite to the lap, since this is the point at which it is necessary to make up for the tension lost by the lapping.

CHAPTER XII.

DIFFERENT TYPES OF ENGINES.

STATIONARY.

So far we have described and referred exclusively to the usual form of the farm traction engine, which is nearly always the simplest kind of an engine, except in one particular, namely, the reverse which gives a variable cut-off. Stationary engines, however, are worked under such conditions that various changes in the arrangement may be made which gives economy in operating, or other desirable qualities. We will now briefly describe some of the different kinds of stationary engines.



D. JUNE & CO.'S STATIONARY FOUR-VALVE ENGINE.

THROTTLING AND AUTOMATIC CUT-OFF TYPES.

Engines may be divided into two classes, namely, throttling and automatic cut-off engines. The throttling engine regulates the speed of the engine by cutting off the supply of steam from the boiler, either by the hand of the engineer on the throttle or by a governor working a special throttling governor valve. Railroad locomotives are throttling engines, and moreover they have no governor, the speed being regulated by the engineer at the throttle valve. Traction engines are usually throttling engines provided with a governor.

An automatic cut-off engine regulates its speed by a governor connected with the valve, and does it by shortening the time during which steam can enter the cylinder. This is a great advantage, in that the expansive power of steam is given a chance to work, while in the throttling engine steam is merely cut off. The subject has been fully discussed under "Economy in Running a Farm Engine." An automatic cut-off engine is much the most economical.

While on traction engines the governor is usually of the ball variety, on stationary engines improved forms of governors are also placed in the fly wheel, and work in various ways, according to the requirements of the valve gear.

THE CORLISS ENGINE.

The Corliss engine is a type now well known and made by many different manufacturers. It is considered one of the most economical stationary engines made, but cannot be used for traction purposes. It may be compound, and may be used with a condenser. It cannot be used as a high speed engine, since the valves will not work rapidly enough.

The peculiarity of a Corliss engine is the arrangement of the valves. It has four valves instead of one, and they are of the semi-rotary type. They consist of a small, long cylinder which rocks back and forth, so as to close and open the port, which is rather wide and short compared to other types. There is a valve at each end of the cylinder opening usually into the clearance space, to admit steam; and two more valves below the cylinder for the exhaust. These exhaust valves allow any water of condensation to run out of the cylinder. Moreover, as the steam when it leaves the cylinder is much colder than when it enters, the exhaust always cools the steam ports, and when the same ports are used for exhaust and admission the fresh steam has to pass through ports that have been cooled and cause condensation. In the Corliss engine the exhaust does not have an opportunity to cool the live steam ports and the condensation is reduced. This works considerable economy.

Also the Corliss valves have little friction from steam pressure on their own backs, since the moment they are lifted from their seats they work freely. The valves are controlled by a governor so as to make the automatic cut-off engine.

The Corliss type of frame for engine is often used on traction engines and means the use of convex shoes on cross-head and concave ways or guides. In locomotive type, cross-head slides in four square angle guides.

THE HIGH SPEED ENGINE.

A high speed engine means one in which the speed of the piston back and forth is high, rather than the speed of rotation, there being sometimes a difference. High speed engines came into use because of the need of such to run dynamos for electric lighting. Without a high speed engine an intermediate gear would have to be used, so as to increase the speed of the operating shaft. In the high speed engine this is done away with.

As an engine's power varies directly as its speed as well as its cylinder capacity or size, an engine commonly used for ten horsepower would become a twenty horsepower engine if the speed could be doubled. So high speed engines are very small and compact, and require less metal to build them. Therefore they should be much cheaper per horsepower.

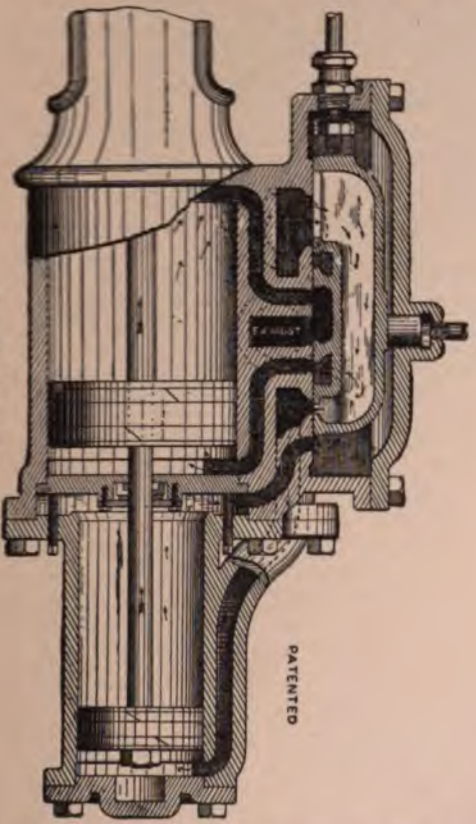
A high speed engine differs from a low speed in no essential particular, except the adjustment of parts. A high steam pressure must be used; a long, narrow valve port is used, so that the full steam pressure may be let on quickly at the beginning of the stroke when the piston is reversing its motion and needs power to get started quickly on its return; the slide valve must be used, since the semi-rotary Corliss would be too wide and short for a quick opening. Some high speed engines are built which use four valves, as does the Corliss. The friction of the slide valve is usually "balanced" in some way, either by "pressure plates" above the valve, which prevent the steam from getting at the top and pressing the valve down, or by letting the steam under the valve, making it slide on narrow strips, since the pressure above would then be reduced in proportion with the smallness of the bearing surface below, and if the bearing surface were very small the pressure above would be correspondingly small, perhaps only enough to keep the valve in place. Some automatic cut-off gear is almost always used. A high speed engine may attain 900 revolutions per minute, 600 being common. In many ways it is economical.

CONDENSING AND NON-CONDENSING.

In the traction engine the exhaust is used in the smokestack to help the draft, since the smokestack must necessarily be short. A stationary engine is usually provided with a boiler set in brickwork, and a furnace with a high chimney, which creates all the draft needed. In other words, the heated gases wasted in a traction engine are utilized to make the draft.

It then becomes desirable to save the power in the exhaust steam in some way. Some of this can be used to heat the feed water, but only a fraction of it.

Now when the exhaust steam issues into the air it must overcome the pressure of the atmosphere, nearly 15 lbs. to the square inch, which is a large item to begin with. This can be saved by letting the steam exhaust into a condenser, where a spray of cold water or the like suddenly condenses the steam so that a vacuum is created. There is then no back pressure on the exhaust steam, theoretically. Practically a perfect vacuum cannot be created, and there is a back pressure of 2 or 3 lbs. per square inch. By the use of a condenser a back pressure of about 12 lbs. is taken off the head of the piston on its return stroke, a matter of considerable economy. But an immense amount of water is required to run a condenser, namely, 20 times as much for a given saving of power as is required in a boiler to make that power. So condensers are used only where water is cheap.



THE WOOLF COMPOUND.

COMPOUND AND CROSS-COMPOUND.

We have already explained the economy effected by the compound engine, in which a large low pressure cylinder is operated by the exhaust from a small high pressure cylinder. In the cut used for illustration the low pressure cylinder is in direct line with the high pressure cylinder, and one piston rod connects both pistons. This arrangement is called the "tandem." Sometimes the low pressure cylinder is placed by the side of the high pressure, or at a distance from it, and operates another piston and connecting rod. By using a steam chest to store the exhaust steam and varying the cut-off of the two cylinders, the crank of the low pressure may be at an angle of 90 degrees with the crank of the high pressure, and there can be no dead center.

When a very high pressure of steam is used the exhaust from the low pressure cylinder may be used to operate a third cylinder; and the exhaust from that to operate a fourth. Engines so arranged are termed triple and quadruple expansion engines, or multiple expansion.

The practical saving of a compound engine when its value can be utilized to the full is 10 per cent to 20 per cent. Small engines are seldom compounded, large engines nearly always.

CHAPTER XIII.

GAS AND GASOLINE ENGINES.

The gas and gasoline engines (they are exactly the same except that one generates the gas it needs from gasoline, while the other takes common illuminating gas, the use of gas or gasoline being interchangeable on the same engine by readjustment of some of the parts) are operated on a principle entirely different from steam. While they are arranged very much as a steam engine, the power is given by an explosion of gas mixed with air in the cylinder. Instead of being a steady pressure like that furnished by steam, it is a sudden pressure given to one end of the piston usually once in four strokes or two revolutions, one stroke being required to draw the gasoline in, the second to compress it, the third to receive the effect of the explosion (this is the only power stroke), the fourth to push out the burned gases preparatory to admitting a new charge. The fact that force is given the cylinder at such wide intervals makes it necessary to have an extra heavy flywheel to keep the engine steady, and the double cylinder engine which can give a stroke at least every revolution is still better and is indispensable when the flywheel cannot be above a certain weight.

For small horsepowers, such as are required for pumping, feed grinding, churning, etc., the gas engine is so much more convenient and so very much cheaper in operation than the small steam engine that it is safe to say that within a very few years the gas engine will have completely displaced the small steam engine. In fact, the discovery of the gas engine permits the same economies for the small engine that the progress in steam engineering has made possible for the large steam engine. As yet the gas engine has made little or no progress against the large steam plant, with its Corliss engine, its triple expansion, its condenser, and all the other appliances which are not practicable with the small engine.

COMPARISON OF STEAM AND GAS ENGINES.

The following points prepared by an experienced farm engine manufacturer will show clearly the advantages of the gas engine over the steam engine for general use about a farm:

In the first place, the farmer uses power, as a rule, at short intervals, and also uses small power. Should he install a steam engine and wish power for an hour or two, it would be necessary for him to start a fire under the boiler and get up steam before he could start the engine. This would take at least an hour. At the end of the run he would have a good fire and good steam pressure, but no use for it, and would have to let the fire die out and the pressure run down. This involves a great waste of water, time and fuel. With a gasoline engine he is always ready and can start to work within a few minutes after he makes up his mind to do so, and he does not have to anticipate his wants in the power line for half a day. Aside from this, in some states, notably Ohio, the law compels any person operating an engine above ten horsepower to carry a steam engineer's license. This does not apply to a gasoline engine.

Again, the gasoline engine is as portable as a traction engine, and can be applied to all the uses of a traction engine and to general farm use all the rest of the year. At little expense it can be fitted up to hoist hay, to pump water, to husk and shell corn, to saw wood, and even by recent inventions to plowing. It is as good about a farm as an extra man and a team of horses.

A gasoline engine can be run on a pint of gasoline per hour for each horsepower, and as soon as the work is done there is no more consumption of fuel and the engine can be left without fear, except for draining off the water in the water jacket in cold weather. A steam engine for farm use would require at least four pounds of coal per horsepower per hour, and in the majority of cases it would be twice that, taking into consideration the amount of fuel necessary to start the fire and that left unburned after the farmer is through with his power. If you know the cost of crude gasoline at your point and the cost of coal, you can easily figure the exact economy of a gasoline engine for your use. To the economy of fuel question may be added the labor or cost of pumping or hauling water.

The only point wherein a farmer might find it advantageous to have a steam plant would be where he is running a dairy and wished steam and hot water for cleansing his creamery machinery. This can be largely overcome by using the water from the jackets which can be kept at a temperature of about 175 degrees, and if a higher temperature is needed he can heat it with the exhaust from the engine. The time will certainly come soon when no farmer will consider himself up to date until he has a gasoline engine.

Some persons unaccustomed to gasoline may wonder if a gasoline engine is as safe as a steam engine. The fact is, they are very much safer, and do not require a skilled engineer to run them. The gasoline tank is usually placed outside the building, where the danger from an explosion is reduced to a minimum. The only danger that may be encountered is in starting the engine, filling the supply tank when a burner near at hand is in flame, etc. Once a gasoline engine is started and is supplied with gasoline, it may be left entirely alone without care for hours at a time without danger and without adjustment.

With a steam engine there is always danger, unless a highly skilled man is watching the engine every moment. If the water gets a little low he is liable to have an explosion; if it gets a little too high he may knock out a cylinder head in his engine; the fire must be fed every few minutes; the grates cleaned. There is always something to be done about a steam engine.

So here is another point of great saving in a gasoline engine, namely, the saving of one man's time. The man who runs the gasoline engine may give nearly all his time to other work, such as feeding a corn-sheller, a fodder chopper, or the like.

Kerosene may also be used in the same way with a special type of gas engine.

The amounts of fuel required of the different kinds possible in a gas engine are compared as follows by Roper:

Illuminating gas, 17 to 20 cubic feet per horsepower per hour.

Pittsburg natural gas, as low as 11 cubic feet.

74° gasoline, known as stove gasoline, one-tenth of a gallon.

Refined petroleum, one-tenth of a gallon.

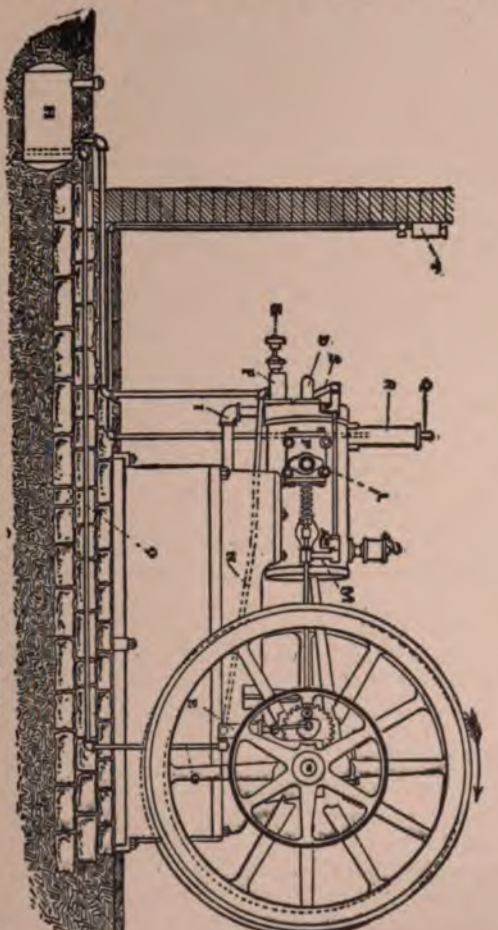
If a gas producing plant using coal supplies the gas, one pound of coal per horsepower per hour is sufficient on a large engine.

DESCRIPTION OF THE GAS OR GASOLINE ENGINE.

The gas engine consists of a cylinder and piston, piston rod, cross-head, connecting rod, crank and flywheel, very similar to those used in the steam engine.

There is a gas valve, an exhaust valve, and in connection with the gas valve a self-acting air valve. The gas valve and the exhaust valve are operated by lever arm or cam worked from the main shaft, arranged by spiral gear or the like so that it gets one movement for each two revolutions of the main shaft. Such an engine is called "four cycle" (meaning one power stroke to each four strokes of the piston), and works as follows:

As the piston moves forward the air and fuel valves are simultaneously opened and closed, starting to open just as the piston starts forward and closing just as the piston completes its forward stroke. Gas and air are simultaneously sucked into the cylinder by this movement. As the cylinder returns it compresses the charge taken in during the forward stroke until it again reaches back center. The mixture in the Otto engine is compressed to about 70 pounds per square inch. Ignition then takes place, causing the mixture to explode and giving the force from which the power is derived. As the crank again reaches its forward center the piston uncovers a port which allows the greater part of the burnt gases to escape. As the piston comes back, the exhaust valve is opened, enabling the piston to sweep out the remainder of the burnt gases. By the time the crank is on the back center the exhaust valve is closed and the engine is ready to take another charge, having com-



FAIRBANKS, MORSE & CO.'S GASOLINE ENGINE.

A is engine cylinder. H is gasoline supply tank located outside of building and under ground. I is air-suction pipe. E is gasoline pump. O is suction pipe from gasoline tank. N is pipe from pump E, leading to reservoir P. Q is igniter tube. R is chimney surrounding tube. T is tank supplying Bunsen burner for heating tube.

pleted two revolutions or four strokes. The side shaft which performs the functions of opening and closing the valves, getting its motion in the Columbus engine by a pair of spiral gears, makes but one revolution to two of the crank shaft.

Gas engines are governed in various ways. One method is to attach a ball governor similar to the Waters on the steam engine. When the speed is too high, the balls go out, and a valve is closed or partly closed, cutting off the fuel supply. Since the engine takes in fuel only once in four strokes, the governing cannot be so close as on the steam engine, since longer time must elapse before the governor can act.

Another type of governor operates by opening the exhaust port and holding it open. The piston then merely draws in air through the exhaust port, but no gas. This is called the "hit or miss" governing type. One power stroke is missed completely.

The heat caused by the explosion within the cylinder is very great, some say as high as 3,000 degrees. Such a heat would soon destroy the oil used to lubricate the cylinder and make the piston cut, as well as destroying the piston packing. To keep this heat down the cylinder is provided with a water jacket, and a current of water is kept circulating around it to cool it off.

When gas is used, the gas is passed through a rubber bag, which helps to make the supply even. It is admitted to the engine by a valve similar to the throttle valve on an engine.

Gasoline is turned on by a similar valve or throttle. It does not have to be gasefied, but is sucked into the cylinder in the form of a spray. As soon as the engine is started, the high heat of the cylinder caused by the constant explosions readily turns the gasoline to gas as it enters. The supply tank of gasoline is placed outside the building, or at a distance, and stands at a point below the feed. A small pump pumps it up to a small box or feed tank, which has an overflow pipe to conduct any superfluous gasoline back to the supply tank. In the gasoline box or feed tank a conical-shaped basin is filled with gasoline to a certain height, which can be regulated. Whatever this conical basin contains is sucked into the cylinder with the air. By regulating the amount in the basin the supply of gasoline in the cylinder can be regulated to the amount required for any given amount of work. In the Columbus engine this regulation is accomplished by screwing the overflow regulator up or down.

There are two methods of igniting the charge in the cylinder in order to explode it. One is by what is called a gasoline or gas torch. A hollow pin or pipe is fixed in the top of the cylinder. The upper part of this pin or pipe runs up into a gasoline or gas lamp of the Bunsen type where it is heated red hot. When the gas and air in the cylinder are compressed by the back stroke of the piston, some of the mixture is forced up into this pipe or tube until it comes in contact with the heated portion and is exploded, together with the rest of the charge in the cylinder. Of course this tube becomes filled with burnt gases which must be compressed before the explosive mixture can reach the heated portion, and no explosion is theoretically possible until the piston causes compression to the full capacity of the cylinder. The length of the tube must therefore be nicely regulated to the requirements of the particular engine used.

The other method is by an electric spark from a battery. Two electrodes of platinum or some similar substance are placed in the compression end of the cylinder. The spark might be caused by bringing the electrodes sufficiently near together at just the right moment, but the more practical and usual way is to break the current, closing it sharply by means of a lever worked by the gearing at just the moment the piston is ready to return after compressing the charge. The electric spark is by long odds the most desirable method of ignition, being safer and easier to take care of, but it requires some knowledge of electricity and electric connection to keep it always in working order.

OPERATION OF GAS AND GASOLINE ENGINES.

To all intents and purposes the operation of a gas or gasoline engine is the same as that of a steam engine with the care of the boiler eliminated. The care of the engine itself is practically the same, though the bearings are relatively larger in a gasoline or gas engine and do not require adjustment so often. Some manufacturers will tell you that a gas engine requires no attention at all. Any one who went on that theory would soon ruin his engine. To keep a gasoline engine in working order so as to get the best service from it and make it last as long as possible, you should give it the best of care.

An engine of this kind needs just as much oiling and cleaning as a steam engine. All bearings must be lubricated and kept free from dirt, great care must be taken that the piston and cylinder are well lubricated. In addition, the engineer must see that the valves all work perfectly tight, and when they leak in any way they must be taken out and cleaned. Usually the valve seats are cast separate from the cylinder, so that they can be removed and ground when they have worn.

Also the water jacket must be kept in order so that the cylinder cannot become too hot.

STARTING A GASOLINE ENGINE.

It is something of a trick to get a gasoline or gas engine started—especially a gasoline engine—and some skill must be developed in this or there will be trouble. This arises from the fact that when an engine has not been running the cylinder is cold and does not readily gasefy the gasoline. At best only a part of a charge of gasoline can be gasefied, and if the cylinder is very cold indeed the charge will not explode at all till the cylinder is warmed up.

When preparing to start an engine, first see that the nuts or studs holding cylinder head to cylinder are tight, as the heating and cooling of the cylinder are liable to loosen them. Then oil all bearings with a hand oil can, and carefully wipe off all outside grease.

When all is ready, work the gasoline pump to get the air out of the feed pipes and fill the reservoir.

First, the engine must be turned so that the piston is as far back as it will go, and to prevent air being pressed back the exhaust must be held open, or a cock in priming cup on top of cylinder opened.

If gasoline priming is needed, the gasoline must be poured into the priming cup after closing the cock into the cylinder, for it would do no good to merely let the gasoline run down into the cylinder in a cold stream: it must be sprayed in. If the exhaust has been held open, and the priming charge of gasoline is to be drawn in through the regular supply pipe and valve, the exhaust should be closed and the throttle turned on to a point indicated by the manufacturer of the engine.

We suppose that the igniter is ready to work. If the hot tube is used, the tube should be hot; if the electric igniter is used, the igniter bar should be in position to be snapped so as to close the circuit and cause a spark when the charge has been compressed.

If all is ready, open the cock from which the supply of gasoline is to be obtained, and at the same time turn the engine over so as to draw the charge into the cylinder. If a priming cock has been opened, that must be closed by hand as soon as the cylinder is filled and the piston ready to return for compression. If the regular feed is used, the automatic valve will close of itself.

Bring the flywheel over to back center so that piston will compress the charge. With the flywheel in the hand, bring the piston back sharply two or three times, compressing the charge. This repeated compression causes a little heat to be liberated, which warms up the cylinder inside. If the cylinder is very cold this compression may be repeated until the cylinder is sufficiently warm to ignite. When performing this preparatory compression the piston may be brought nearly up to the dead center but not quite. At last bring it over the dead center, and just as it passes over, snap the electric ignition bar. If an explosion follows the engine will be started.

If the hot tube is used, the flywheel may be brought around sharply each time so that the piston will pass the dead center, as an explosion will follow complete compression. If the explosion does not follow, the flywheel may be turned back again and brought up sharply past the dead center. Each successive compression will warm up the cylinder a little till at last an explosion will take place and the engine will be started.

More gasoline will be needed to start in cold weather than in warm, and the starting supply should be regulated accordingly. Moreover, when the engine gets to going, the cylinder will warm up, more of the gasoline will vaporize, and a smaller supply will be needed. Then the throttle can be turned so as to reduce the supply.

After the engine is started, the water jacket should be set in operation, and you should see that the cylinder lubrication is taking place as it ought.

As the above method of starting the engine will not always work well, especially in cold weather, what are called "self-starters" are used. They are variously arranged on different engines, but are constructed on the same general principle. This is, first, to pump air and gasoline into the cylinder instead of drawing it in by suction. Sometimes the gasoline is forced in by an air compression tank. The engine is turned just past the back center, care having been taken to make sure that the stroke is the regular explosion stroke. This may be told by looking at the valve cam or shaft. If an electric igniter is used, it is set ready to snap by hand. If the tube igniter is used, a detonator is arranged in the cylinder, to be charged by the head of a snapping parlor match which can be exploded by hand. Holding the flywheel with one hand with piston just past back center, fill the compressed end of the cylinder by working the pump or turning on the air in compression tank till you feel a strong pressure on the piston through the flywheel. Then snap igniter or detonator and the engine is off. If throttle valve has not been opened, it may now be immediately opened.

The skill comes in managing the flywheel with one hand, or one hand and a foot, and the igniter, etc., with the other hand. Care must be exercised not to get caught when the flywheel starts off. The foot must never be put through the arm of the wheel, the wheel merely being held when necessary by the ball of the big toe, so that if the flywheel should start suddenly it would merely slip off the toe without carrying the foot around or unbalancing the engineer. Until one gets used to it, it is better to have some one else manage the flywheel, while you look after the gasoline supply, igniter, etc. When used to it, one man can easily start any gasoline engine up to 15 horsepower.

WHAT TO DO WITH A GASOLINE ENGINE WHEN IT DOESN'T WORK.

Questions and Answers.

Q. If the engine suddenly stops, what would you do?

A. First, see that the gasoline feed is all right, plenty of gasoline in the tank, feed pipe filled, gasoline pump working, and then if valves are all in working order. Perhaps there may be dirt in the feed reservoir, or the pipe leading from it may be stopped up. If everything is right so far, examine the valves to see that they work freely and do not get stuck from lack of good oil, or from use of poor oil. Raise them a few times to see if they work freely. Carefully observe if the air valve is not tight in sleeve of gas valve.

Q. What would be the cause of the piston's sticking in the cylinder?

A. Either it was not properly lubricated, or it got too hot, the heat causing it to expand.

Q. Are boxes on a gasoline engine likely to get hot?

A. Yes, though not so likely as on a steam engine. They must be watched with the same care as they would be on a steam engine. If the engine stops, turn it by hand a few times to see that it works freely without sticking anywhere.

Q. Is the electric sparking device likely to get out of order?

A. Yes. You can always test it by loosening one wire at the cylinder and touching it to the other to see that a spark passes between them. If there is no spark, there is trouble with the battery.

Q. How should the batteries be connected up?

A. A wire should pass from carbon of No. 1 to copper of No. 2; from carbon of No. 2 to copper of No. 3, etc., always from copper to carbon, never from carbon to carbon or copper to copper. Wire from last carbon to spark coil and from coil to switch, and from switch to one of the connections on the engine. Wire from copper of No. 1 to the other connection on the engine. In wiring, always scrape the ends of the wire clean and bright where the connection is to be made with any other metal.

Q. What precautions can be taken to keep batteries in order?

A. The connections between the cells can be changed every few days, No. 1 being connected with No. 3, No. 3 with No. 5, etc., alternating them, but always making a single line of connection from one connection on cylinder to first copper, from the carbon of that cell to copper of next cell, and so on till the circuit to the cylinder is completed. When the engine is not in operation, always throw out the switch, to prevent possible short circuiting. If battery is feeble at first, fasten wires together for half an hour at engine till current gets well started.

Q. Is there likely to be trouble with the igniter inside cylinder?

A. There may be. You will probably find a plug that can be taken out so as to provide a peep hole. Never put your eye near this hole, for some gasoline may escape and when spark is made it will explode and put out your eye. Always keep the eye a foot away from the hole. Practice looking at the spark when you know it is all right and no gasoline is near, in order that you may get the right position at which to see the spark in case of trouble. In any case, always take pains to force out any possible gas before snapping igniter to see if the spark works all right.

Q. If there is no spark, what should be done?

A. Clean the platinum points. This may be done by throwing out switch and cutting a piece of pine one-eighth of an inch thick and one-half inch wide, and rubbing it between the points. It may be necessary to push cam out a trifle to compensate for wear.

Q. How can you look into peep hole without endangering eyesight?

A. By use of a mirror.

Q. If the hot tube fails to work, what may be done?

A. Conditions of atmosphere, pressure, etc., vary so much that the length of the tube cannot always be determined. If a tube of the usual length fails to work, try one a little longer or shorter, but not varying over 1½ inches.

Q. When gas is used, what may interfere with gas supply?

A. Water in the gas pipes. This is always true of gas pipes not properly drained, especially in cold weather when condensation may take place. If water accumulates, tubes must be taken apart and blown out, and if necessary a drain cock can be put in at the lowest point.

Q. What trouble is likely to be had with the valves?

A. In time the seats will wear, and must be taken out and ground with flour or emery.

Q. Should the cylinder of a gasoline engine be kept as cool as it can be kept with running water?

A. No. It should be as hot as the hand can be borne upon it, or about 100 degrees. If it is kept cooler than this the gasoline will not gasefy well. If a tank is used, the circulation in the tank will justify the temperature properly. The water may be kept at 175 degrees of temperature, and used for hot water heating. The exhaust gases are also hot and may be used for heating by carrying in pipes coiled in a hot water heater.

Q. Are water joints likely to leak?

A. Yes. The great heating given the cylinder is liable to loosen the water joints. They are best packed with asbestos soaked in oil, sheets 1-16 inch thick. Old packing should always be thoroughly cleaned off when new packing is put in.

Q. How may the bearings be readjusted when worn?

A. Usually there are liners to adjust bearing. In crank box adjust as in steam engine by tightening the key.

Q. If you hear a loud explosion in the exhaust pipe after the regular explosion, should you be alarmed?

A. No. All gas or gasoline engines give them at times and they are harmless. If the gas or gasoline fed to the engine is not sufficient to make an explosive mixture, the engine will perhaps miss the explosion, and live gas will go into the exhaust pipe. After two or three of these have accumulated an explosion may take place and the burned gases coming out of the port as hot flames will explode the live gas previously exhausted. Any missing of the regular explosion by the engine, through trouble with battery, or the like, will cause the same condition.

Q. When you get exhaust pipe explosions, what should you do?

A. Turn on the fuel till the exhaust is smoky. Then you know you have fuel enough and more than enough. If the explosions still continue, conclude that the igniter spark is too weak, or does not take place.

Q. What precaution must be taken in cold weather?

A. The water must be carefully drained out of jacket.

Q. Will common steam engine cylinder oil do for a gasoline engine?

A. No. The heat is so great that only a special high grade mineral oil will do. Any oil containing animal fat will be worse than useless.

Q. How can you tell if right amount of gas or gasoline is being fed to engine to give highest power?

A. Turn on as much as possible without producing smoke. A smokeless mixture is better than one which causes smoke.

Q. If you have reason to suppose gas may be in the cylinder, should you try to start cylinder?

A. No. Empty the gas all out by turning the engine over a few times by hand, holding exhaust open if necessary.

Q. How long will a battery run without recharging?

A. The time varies. Usually not over three or four months.

Q. Is it objectionable to connect an electric bell with an engine battery?

A. Certainly. Never do it.

Q. If your engine doesn't run, how many things are likely to be the trouble?

A. Not more than four—compression, spark, gas supply, valves.

CHAPTER XIV.

HOW TO RUN A THRESHING MACHINE.

A threshing machine, though large, is a comparatively simple machine, consisting of a cylinder with teeth working into other teeth which are usually concaved (this primary part really separates the grain from the husk), and rotary fan and sieves to separate grain from chaff, and some sort of stacker to carry off the straw. The common stacker merely carries off the straw by some endless arrangement of slats working in a long box; while the so-called "wind stacker" is a pneumatic device for blowing the straw through a large pipe. It has the advantage of keeping the straw under more perfect control than the common stacker. The separation of the grain from the straw is variously effected by different manufacturers, there being three general types, called apron, vibrating, and agitating.

The following list of parts packed inside the J. I. Case separator (of the agitative type) when it is shipped will be useful for reference in connection with any type of separator:

2 Hopper arms, Right and Left,
1 Hopper bottom,
1 Hopper rod with thumb nut,
2 Feed tables,
2 Feed table legs,
2 Band cutter stands and bolts,
1 Large crank shaft,
1 Grain auger with 1223 T. pulley and 1154 T., Box,
1 Tailings auger,
1 Elevator spout,
1 Elevator shake arm, complete,
1 Set fish-backs, for straw-rack,
1 Elevator pulley, 529 T.,
1 Beater pulley, 6-inch 1254 T., or 4-inch 1255 T.,
1 Elevator drive pulley 1673 T.,
1 Crank pulley to drive grain auger 1605 T.,

1 Cylinder pulley to drive crank 4-inch 973 T., or 6-inch 1085 T.,
1 Cylinder pulley to drive fan 1347 T., 1348 T., or 1633 T.,
1 Fan pulley, 1244 T.; or 1231 T.,
1 Belt tightener, complete, with pulley,
1 Belt reel, 5016 T., or 1642 T., with crank and bolt,
4 Shoe sieves,
4 Shoe rods, with nuts and washers,
1 Conveyor extension,
1 Sheet iron tail board,
2 Tail board castings 1654 T., and 1655 T.

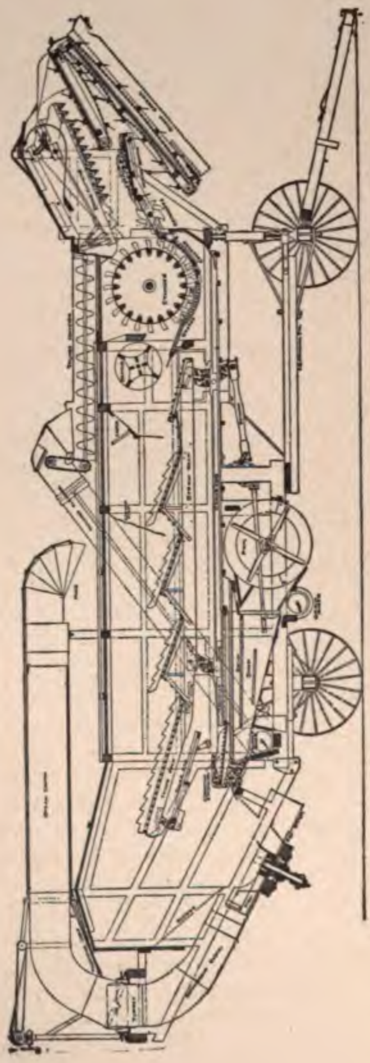
In addition to these are the parts of the stacker.

As each manufacturer furnishes all needed directions for putting the parts together, we will suppose the separator is in working condition.

A new machine should be set up and run for a couple of hours before attempting to thresh any grain. The oil boxes should be carefully cleaned, and all dirt, cinders, and paint removed from the oil holes. The grease cups on cylinder, beater and crank boxes should be screwed down after being filled with hard oil, moderately thin oil being used for other parts of the machine. Before putting on the belts, turn the machine by hand a few times to see that no parts are loose. Look into the machine on straw rack and conveyor.

First connect up belt with engine and run the cylinder only for a time. Screw down the grease cup lugs when necessary, and see that no boxes heat. Take off the tightener pulley, clean out oil chambers and thoroughly oil the spindle. Then oil each separate bearing in turn, seeing that oil hole is clean, and that pulley or journal works freely. The successive belts may then be put on one at a time, until the stacker belt is put on after its pulleys have been oiled. Especially note which belts are to run crossed—usually the main belt and the stacker belt. You can tell by noting which way the machinery must run to keep the straw moving in the proper direction.

Oiling on the first run of a machine is especially important, as the bearings are a trifle rough and more liable to heat than after machine has been used for some time.



SECTIONAL VIEW OF THE AGITATOR SEPARATOR.

It is well to oil a shaft while it runs, since the motion helps the oil to work in over the whole surface.

The sieves, concaves, check board and blinds must be adjusted to the kind of grain to be threshed. When they have been so adjusted the machine is ready to thresh.

SETTING SEPARATOR.

It is important that the machine be kept perfectly steady, and that it be level from side to side, though its being a little higher or lower at one end or the other may not matter much. If the level sidewise is not perfect the grain will have a tendency to work over to one side. A spirit level should be used.

One or more of the wheels should be set in holes, according to the unevenness of the ground, and the rear wheels should be well blocked. Get the holes ready, judging as well as possible what will give a true level and a convenient position. Haul the machine into position and see that it is all right before uncoupling the engine. If holes need redigging to secure proper level, machine may be pulled out and backed in again by the engine. When machine is high in front it can easily be leveled when engine or team have been removed, by cramping the front wheels and digging in front of one and behind the other, then pulling the tongue around square.

Block the right hind wheel to prevent the belt drawing machine forward. Always carry a suitable block to have one handy.

In starting out of holes or on soft ground, cramp the front axle around, and it will require only half the power to start that would be required by a straight pull.

In setting the machine, if the position can be chosen, choose one in which the straw will move in the general direction of the wind, but a little quartering, so that dust and smoke from engine will be carried away from the men and the straw stack. In this position there is less danger from fire when wood is used.

THE CYLINDER.

The cylinder is arranged with several rows of teeth working into stationary teeth in what is called the concave. It is important that all these teeth be kept tight, and that the cylinder should not work from side to side. The teeth are liable to get loose in a new machine, and should be tightened up frequently. A little brine on each nut will cause it to rust slightly and help to hold it in place. If the cylinder slips endwise even a sixteenth of an inch, the teeth will be so much nearer the concaves on one side and so much farther away from them on the other side. Where they are close, they will crack the grain; where they are wide apart they will let the straw go through without threshing or taking out the grain. So it is important that the cylinder and its teeth run true and steady. If the teeth get bent in any way, they must be straightened.

The speed of the cylinder is important, since its pulley gives motion to the other parts of the machine, and this movement must be up to a certain point to do the work well. A usual speed for the cylinder pulley is 1,075 revolutions per minute, up to 1,150.

There is always an arrangement for adjusting the cylinder endwise, so that teeth will come in the middle. This should be adjusted carefully when necessary. The end play to avoid heating may be about 1-64 of an inch. It may be remembered that the cylinder teeth carry the straw to the concaves, and the concaves do the threshing.

THE CONCAVES.

The concaves are to be adjusted to suit the kind of grain threshed. When desiring to adjust concaves, lift them up a few times and drop so as to jar out dust. Wedging a block of wood between cylinder teeth and concaves will in some types of separator serve to bring up concaves when cylinder is slowly turned by hand.

There are from two to six rows of teeth in the concave, and usually the number of rows is adjustable or variable. Two rows will thresh oats, where six are required for flax and timothy. Four rows are commonly used for wheat and barley. The arrangement of rows of teeth and blanks is important. When four rows are used, one is commonly placed well back, one front, blank in the middle. When straw is dry and brittle, cylinder can be given "draw" by placing blank in front. Always use as few teeth and leave them as low as possible to thresh clean, since with more teeth than necessary set higher than required the straw will be cut up and a great deal of chopped straw will get into the sieves, all of which also requires additional power. Sometimes the teeth can be taken out of one row, so that one, three, or five rows may be used. For especially difficult grain like Turkey wheat, a concave with corrugated teeth may be used, in sets of three rows each up to nine rows. The corrugated teeth are used for alfalfa in localities where much is raised.

THE BEATER AND CHECK BOARD.

After the cylinder has loosened the grain from the husk and straw, it must still be separated. Some threshers have a grate under the cylinder and behind it. In any case the beater causes the heavy grain to work toward the bottom, and the check board keeps the grain from being carried to rear on top of the straw, where it would not have a chance to become separated. If the grain is very heavy or damp, there may be a tendency for the straw to stick to the cylinder and be carried around too far. In such a case the beater should be adjusted to give more space, and the check board raised to allow the straw to pass to the rear freely.

STRAW RACK.

The straw rack and conveyor carry the straw and grain to the rear with a vibratory movement, causing the grain to be shaken out. To do good work the straw rack must move with a sufficient number of vibrations per minute, say 230. A speed indicator on the crank shaft will show the number of vibrations best. Great care must be taken with this part of the thresher, or a great deal of grain will be carried into the straw. The less the straw is cut up, the better this portion of the machine works; so the smallest practicable number of teeth in the concave should be used.

The crank boxes and pitmans should be adjusted so that there is no pounding. If the rear vibrating arms drop too low they get below the dead center and are liable to break, at any rate causing severe pounding and hard running. To prevent this, the crank boxes can be moved forward by putting leather between them and the posts, or should be otherwise adjusted. The trouble being due to the pitmans having worn short, the pitmans may be lengthened in some way by putting pieces of leather over the end or the like, or new pitmans may be introduced.

THE FAN.

The chief difficulty likely to arise with the fan is blowing over grain. To prevent this blinds are usually arranged, which may be adjusted while the machine is running so as to prevent the grain from being blown over. At the same time it is important to clean the grain, so the adjustment should not go to one extreme or the other.

In windy weather the blinds should be closed more on one side than on the other. The speed of the fan must be adjusted to the requirements of the locality.

As much blast should be used as the grain will stand, and heavy feeding requires more wind than light feeding, since the chaff checks the blast to a certain extent.

Care should be taken that the wind board over the grain auger does not get bent, and it should be adjusted so that the strongest part of the blast will come about the middle of the sieve.

SIEVES.

There is usually one conveyor sieve, which causes the grain to move along, and shoe sieves, which are required to clean the grain thoroughly. Different kinds of sieves are provided for different kinds of grain, and the proper selection and adjustment of these sieves as to mesh, etc., is of the utmost importance.

Much depends on the way the sieves are set, and on the rate at which the thresher is fed, or the amount of work it is really doing. The best guide is close observation and experience, both your own and that of other threshermen.

CONVEYOR EXTENSION.

This carries the coarse chaff from the conveyor sieve to the stacker. The conveyor sieve should be coarse enough to let all the good grain through, as whatever is carried on to the extension must be returned with the tailings to the cylinder. This means so much waste work. The conveyor extension is removable, and should always be tight before machine is started. See that it is.

When necessary, the grain may be run over a screen, which differs from a sieve in that the mesh is small and intended to let dust and small chaff through while the grain does not pass. The refuse from the screen is dropped onto the ground. All screens have a tendency to become clogged, and in this condition obstruct the grain and wind. It is desirable not to use them except when necessary, and if used they should be frequently cleaned.

TAILINGS ELEVATOR.

The tailings are carried back to the cylinder by an elevator usually worked with a chain. This chain should be kept tight enough not to unhook, yet not so tight as to bind.

To put the chain into the elevator, tie a weight on a rope and drop it down the lower part of the elevator. The chain may be fastened to the rope and a man at the top can then pull the chain up, while another feeds it in at the bottom. When chain has been drawn up to the top, the rope should be dropped down upper portion of elevator and used at bottom to pull chain down after it has been adjusted over the sprocket. Some one at the bottom should continue to feed the chain in as it is pulled down, so that it will go into the elevator straight. When the chain has been pulled through it may be hooked and adjusted to lower sprocket, and tightened up by screws at top. Turn the chain around once by hand to make sure there are no kinks in it.

The tailings should be small, containing no light chaff and little full-size grain. They are a good indication of how the sieves are working. If much good grain is coming through, see if it gets over the conveyor sieve by way of the extension to the tailings auger, or over the shoe sieve. If the sieves are not right, they may be adjusted in various ways, according to the directions of the manufacturer.

Grain returned in the tailings is liable to get cracked in the cylinder, and much chaff in the tailings chokes the cylinder. For every reason, the tailings should be kept as low as possible.

SELF-FEEDER.

The self-feeder is arranged to cut the bands of the sheaves and feed the grain to the cylinder automatical

It has a governor to prevent crowding in too much grain, and usually a change of pulleys for slow or fast feeding, as circumstances may require. In starting a new governor the friction pulley and inside of the band should have paint scraped off, and a little oil should be put on face of friction wheel. The carrier should not start till the machine attains full threshing motion, and to prevent this a few sheaves should be laid upon it. The knife arms should be raised or lowered to adjust them to the size of the sheaves and condition of the grain for cutting bands.

The cranks and carrier shaft boxes should be oiled regularly, but the friction bands should not be oiled after it once becomes smooth.

THE WIND STACKER.

The wind stacker is arranged to swing by a hand-wheel or the like, and also automatically.

Great care should be taken not to use the hand moving apparatus when the stacker is set for automatic moving, as a break is liable to follow. There is a clutch to stop the stacker, however. At times it will be more convenient to leave off the belt that causes the automatic movement.

By the use of various pulleys the speed of the stacker may be altered, and it should be run no faster than is necessary to do the work required, which will depend on the character of the straw. Any extra speed used will add to the cost of running the engine and is a loss in economy.

In moving machine with wind stacker in place, care should be taken to see that it rests in its support before machine moves.

The canvas curtain under the decking, used to turn the straw into the hopper, may need a piece of wood fastened to its lower edge to keep it more stiff when stiff rye straw is passing. The bearings of the fan and jack shafts should be kept well lubricated with hard oil, and the bevel gears should be kept well greased with axle grease applied with a stick. Other bearings and worm gear of automatic device should be oiled with soft oil.

The attached stacker is simple in operation, and if it is desired not to use the automatic swinging device but swing by hand, the automatic gear may be thrown out. An independent stacker is managed in much the same way.

ATTACHMENTS.

A weigher, bagger, and a high loader are usually used with a separator. Their operation is simple, and depends upon the particular type or make.

BELTING.

The care of the belting is one of the most important things about the management of a threshing machine, and success or failure will depend largely on the condition in which the belts are kept. Of course the hair side should be run next the band wheel. Once there was disagreement among engineers on this point, but it has been conclusively proven that belts wear longer this way and get better friction, for the simple reason that the flesh side is more flexible than the hair side, and when on the outside better accommodates itself to the shape of the pulley. If the hair side is outermost, it will be stretched more or less in going around the pulley and in time will crack. Rubber belts must be run with the seam on the outside.

When leather belts become hard they should be softened with neatsfoot oil. A flexible belt is said to transmit considerably more power than a hard one.

Pulleys must be kept in line or the belt will slip off. When pulleys are in line the belt has a tendency to work to the tightest point. Hence pulleys are usually made larger in the middle, which is called "crowning."

Belts on a separator should be looked over every day, and when any lacing is worn, it should be renewed at once. This will prevent breaks during working, with loss of time. Some threshermen carry an extra set of belts to be ready in case anything does break, and they assert that they save money by so doing.

Lacing is not stronger in proportion as it is heavy. If it is heavy and clumsy it gets strained in going round the pulley, and soon gives out. The ideal way to lace a belt is to make it as nearly like the rest of the belt as possible, so that it will go over the pulleys without a jar. The ends of the belt should be cut off square with a try square, and a small punch used for making holes. Holes should be equally spaced, and outside ones not so near the edge as to tear out. The rule is a hole to every inch of the belt, and in a leather belt they may be as close as a quarter of an inch to the ends without tearing out. Other things being equal, the nearer the ends the holes are the better, as belt will then pass over pulley more easily. The chief danger of tearing is between the holes.

A stacker web belt may be laced by turning the ends up and lacing them together flat at right angles to rest of belt. Rubber or cotton belting that does not run over idler or tightener pulleys so that both sides must be smooth may be laced in this way. This lacing lasts two or three times as long with such belts as any other, for the reason that the string is not exposed to wear and there is no straining in passing round pulleys.

The ordinary method of lacing a leather belt is to make the laces straight on the pulley side, all running in the same direction as the movement of the belt, and crossing them on the outside diagonally in both directions. When belts run on pulleys on both sides, as they do on the belt driving beater and crank, and also on wind stacker, a hinge lacing may be made by crossing the lacing around the end of the belt to the next adjacent hole opposite, the lacing showing the same on both sides. This allows the belt to bend equally well either way.

The best way to fasten a lacing is to punch a hole where the next row of lace holes would come when the belt is cut off, and after passing the lace through this hole, bring the end around and force it through again, cutting the end off short after it has passed through. This hole must be small enough to hold the lace securely, and care should be taken that it is in position to be used as a lace-hole the next time a series of holes is required.

New belts stretch a good deal, and the ends of the lacing should not be cut off short till the stretch is taken out of the belts.

Belting that has got wet will shrink and lacing must be let out before belt is put on again. Tight belts have been known to break the end of a shaft off, and always cause unnecessary friction.

Cotton or Gandy belting should not be punched for lacing, but holes made with a pointed awl, since punching cuts some of the threads and weakens belt.

HOW TO BECOME A GOOD FEEDER.

The art of becoming a good feeder will not be learned in a day. The bundles should be tipped well up against the cylinder cap, and flat bundles turned on edge, so that cylinder will take them from the top. It is not hard to spread a bundle, and in fast threshing a bundle may be fed on each side, each bundle being kept pretty well to its own side, while the cylinder is kept full the entire width. A good feeder will keep the straw carrier evenly covered with straw, and will watch the stacker, tailings and grain elevator and know the moment anything goes wrong.

WASTE.

No threshing machine will save every kernel of the grain, but the best results can be attained only by care and judgment in operating.

It is easy to exaggerate the loss of grain, for if a very small stream of grain is seen going into the straw it will seem enormous, though it will not amount to a bushel a day. There are practically a million kernels of wheat in a bushel, or 600 handfuls, and even if a handful is wasted every minute, it would not be enough to counterbalance the saving in finishing a job quickly.

Of course, waste must be watched, however, and checked if too great. First determine whether the grain is carried over in the straw or the waste is at the shoe sieve.

If the waste is in the conveyor sieve, catch a handful of the chaff, and if grain is found, see whether the sieve is the proper mesh. Too high a speed will cause grain to be carried over. If too many teeth are used in the concave, the conveyor sieve will be forced to carry more chaff than it can handle. The blast may be too strong and carry over grain, so adjust the blinds that the blast will be no stronger than is necessary to clean the wheat well and keep sieves free. If grain is still carried over, the conveyor sieve may be adjusted for more open work, but care should be taken not to overwork the shoe sieve. Be careful that the wind board is not bent so that some grain will go into the fan and be thrown out of the machine altogether.

If the grain is not separated from the straw thoroughly, it may be due to "slugging" the cylinder (result of poor feeding), causing a variable motion. It may also be because speed of crank is not high enough. Check board should be adjusted as low as possible to prevent grain being carried on top of straw. See that cylinder and concave teeth are properly adjusted so as not to cut up straw, while at the same time threshing out all the grain. Sometimes heads not threshed out by the cylinder will be threshed out by the fan of the wind stacker, and the fault will be placed on the separating portions instead of on the imperfect cylinder.

Grain passes through the cylinder at the rate of about a mile a minute. The beater reduces this to 1,500 feet per minute. After passing the check board the straw moves about 36 feet per minute. At these three different speeds the straw passes the 17 feet length of the machine in about 25 seconds. The problem is to stop the grain while the straw is allowed to pass out. Evidently there must be a small percentage of loss, and there is always a limit as to what it will pay to try to save. Each man must judge for himself.

BALANCING A CYLINDER.

A cylinder should be so balanced that it will come to rest at any point. In a rough way a cylinder may be balanced by placing the journals on two carpenter's squares laid on saw-horses. Gently roll the cylinder back and forth and every time it stops, make a chalk mark on the uppermost bar. If the same bar comes up three times in succession it probably is light, and a wedge should be driven under center band at chalk mark. Continue experimenting until cylinder will come to rest at any point.

COVERING PULLEYS.

This is easily done, but care must be taken that the leathers are tight or they will soon come off.

To cover a cylinder pulley, take off what remains of the old cover, pull out the nails, and renew the wedges if necessary. Select a good piece of leather a little wider than face of pulley and about four inches longer than enough to go around. Soak it in water for about an hour. Cut one end square and nail it to the wedges, using nails just long enough to clinch. Put a clamp made of two pieces of wood and two bolts on the leather, block the cylinder to keep it from turning, and by means of two short levers pry over the clamp to stretch the leather. Nail to the next wedges, move the clamp and nail to each in turn, finally nailing to the first one again before cutting off. Trim the edges even with the rim of the pulley.

The same method may be used with riveted covers.

CARE OF A SEPARATOR.

A good separator ought to last ten years, and many have been in use twice that time. After the season is over the machine ought to be thoroughly cleaned and stored in a dry place. Dirt on a machine holds moisture and will ruin a separator during a winter if it is left on. It also causes the wood to rot and sieves and iron work to rust.

Once in two years at least a separator ought to have a good coat of first-class coach varnish. Before varnishing, clean off all grease and oil with benzine and see that paint is bright.

At the beginning of the season give the machine a thorough overhauling, putting new teeth in cylinder if any are imperfect, and new slats in stacker web or straw rack if they are needed. Worn boxes should be taken up or rebabbitted, and conveyor and shoe eccentric placed if worn out. Tighten nuts, replace lost bolts, leaving the nut always turned square with the piece it rests on. Every separator ought to be covered with a canvas during the season. It will pay.

The right and left sides of a threshing machine are reckoned from the position of the feeder as he stands facing the machine.

In case of fire, the quickest way is to let the engine pull the machine out by the belt. Take blocks away from wheels, place a man at end of tongue to steer, and back engine slowly. If necessary, men should help the wheels to start out of holes or soft places.

Watch the forks of the pitchers to see that none are loose on the handles, especially if a self-feeder is used. A pitchfork in a separator is a bad thing.

CHAPTER XV.

QUESTIONS ASKED ENGINEERS WHEN APPLYING FOR A LICENSE.*

Q. If you were called on to take charge of a plant, what would be your first duty?

A. To ascertain the exact condition of the boiler and all its attachments (safety valve, steam gauge, pump, injector), and engine.

Q. How often would you blow off and clean your boilers if you had ordinary water to use?

A. Once a month.

Q. What steam pressure will be allowed on a boiler 50 inches diameter ⅜ inch thick, 60,000 T. S. 1-6 of tensile strength factor of safety?

A. One-sixth of tensile strength of plate multiplied by thickness of plate, divided by one-half of the diameter of boiler, gives safe working pressure.

Q. How much heating surface is allowed per horse power by builders of boilers?

A. Twelve to fifteen feet for tubular and flue boilers.

Q. How do you estimate the strength of a boiler?

A. By its diameter and thickness of metal.

Q. Which is the better, single or double riveting?

A. Double riveting is from sixteen to twenty per cent stronger than single.

Q. How much grate surface do boiler makers allow per horse power?

A. About two-thirds of a square foot.

Q. Of what use is a mud drum on a boiler, if any?

A. For collecting all the sediment of the boiler.

Q. How often should it be blown out?

A. Three or four times a day.

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*Furnished by courtesy of a friend of Aultman & Taylor Co.

Q. Of what use is a steam dome on a boiler?

A. For storage of dry steam.

Q. What is the object of a safety valve on a boiler?

A. To relieve pressure.

Q. What is your duty with reference to it?

A. To raise it twice a day and see that it is in good order.

Q. What is the use of check valve on a boiler?

A. To prevent water from returning back into pump or injector which feeds the boiler.

Q. Do you think a man-hole in the shell on top of a boiler weakens it any?

A. Yes, to a certain extent.

Q. What effect has cold water on hot boiler plates?

A. It will fracture them.

Q. Where should the gauge cock be located?

A. The lowest gauge cock ought to be placed about an inch and a half above the top row of flues.

Q. How would you have your blow-off located?

A. In the bottom of mud-drum or boiler.

Q. How would you have your check valve arranged?

A. With a stop cock between check and boiler.

Q. How many valves are there in a common plunger force pump?

A. Two or more—a receiving and a discharge valve.

Q. How are they located?

A. One on the suction side, the other on the discharge.

Q. How do you find the proper size of safety valves for boilers?

A. Three square feet of grate surface is allowed for one inch area of spring loaded valves; or two square feet of grate surface to one inch area of common lever valves.

Q. Give the reasons why pumps do not work sometimes?

A. Leak in suction, leak around the plunger, leaky check valve, or valves out of order, or lift too long.

Q. How often ought boilers to be thoroughly examined and tested?

A. Twice a year.

Q. How would you test them?

A. With hammer and with hydrostatic test, using warm water.

Q. Describe the single acting plunger pump; how it gets and discharges its water?

A. The plunger displaces the air in the water pipe, causing a vacuum which is filled by the atmosphere forcing the water therein; the receiving valve closes and the plunger forces the water out through the discharge valve.

Q. What is the most economical boiler-feeder?

A. The (Trix) Exhaust Injector.*

Q. What economy is there in the Exhaust Injector?

A. From 15 to 25 per cent saving in fuel.

Q. Where is the best place to enter the boiler with the feed water?

A. Below the water level, but so that the cold water can not strike hot plates. If injector is used this is not so material as feed water is always hot.

Q. What are the principal causes of priming in boilers?

A. To high water, not steam room enough, misconstruction, engine too large for boiler.

Q. How do you keep boilers clean or remove scale therefrom?

A. The best "scale solvent" and "feed water purifier" is an honest, intelligent engineer who will regularly open up his boilers and clean them thoroughly, soaking boilers in rain water now and then.

Q. If you found a thin plate, what would you do?

A. Put a patch on it.

Q. Would you put it on the inside or outside?

A. Inside.

Q. Why so?

A. Because the action that has weakened the plate will then set on the patch, and when this is worn it can be repeated.

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*So says one expert. Others may think otherwise.

Q. If you found several thin places, what would you do?

A. Patch each and reduce the pressure.

Q. If you found a blistered plate?

A. Put a patch on the fire side.

Q. If you found a plate on the bottom buckled?

A. Put a stay through the center of buckle.

Q. If you found several of the plates buckled?

A. Stay each and reduce the pressure.

Q. What is to be done with a cracked plate?

A. Drill a hole at each end of crack, caulk the crack and put a patch over it.

Q. How do you change the water in the boiler when the steam is up?

A. By putting on more feed and opening the surface blow cock.

Q. If the safety valve was stuck how would you relieve the pressure on the boiler if the steam was up and could not make its escape?

A. Work the steam off with engine after covering fires heavy with coal or ashes, and when the boiler is sufficiently cool put safety valve in working order.

Q. If water in boiler is suffered to get too low, what may be the result?

A. Burn top of combustion chamber and tubes, perhaps cause an explosion.

Q. If water is allowed to get too high, what result?

A. Cause priming, perhaps cause breaking of cylinder covers or heads.

Q. What are the principal causes of foaming in boilers?

A. Dirty and impure water.

Q. How can foaming be stopped?

A. Close throttle and keep closed long enough to show true level of water. If that level is sufficiently high, feeding and blowing off will usually suffice to correct the evil.

Q. What would you do if you should find your water gone from sight very suddenly?

A. Draw the fires and cool off as quickly as possible

Never open or close any outlets of steam when your water is out of sight.

Q. What precautions should you take to blow down a part of the water in your boiler while running with a good fire?

A. Never leave the blow-off valve, and watch the water level.

Q. How much water would you blow off at once while running?

A. Never blow off more than one gauge of water at a time while running.

Q. What general views have you in regard to boiler explosions—what is the greatest cause?

A. Ignorance and neglect are the greatest causes of boiler explosions.

Q. What precaution should the engineer take when necessary to stop with heavy fires?

A. Close dampers, put on injector or pump and if a bleeder is attached, use it.

Q. Where is the proper water level in boilers?

A. A safe water level is about two and a half inches over top row of flues.

Q. What is an engineer's first duty on entering the boiler room?

A. To ascertain the true water level.

Q. When should a boiler be blown out?

A. After it is cooled off, never while hot.

Q. When laying up a boiler what should be done?

A. Clean thoroughly inside and out; remove all oxidation and paint places with red lead; examine all stays and braces to see if any are loose or badly worn.

Q. What is the last thing to do at night before leaving plant?

A. Look around for greasy waste, hot coals, matches, or anything which could fire the building.

Q. What would you do if you had a plant in good working order?

A. Keep it so, and let well enough alone.

Q. Of what use is the indicator?

A. The indicator is used to determine the indic power developed by an engine, to serve as a guide in setting valves and showing the action of the steam in the cylinder.

Q. How would you increase the power of an engine?

A. To increase the power of an engine, increase the speed; or get higher pressure of steam, use less expansion.

Q. How do you find the horsepower of an engine?

A. Multiply the speed of piston in feet per minute by the total effective pressure upon the piston in pounds and divide the product by 33,000.

Q. Which has the most friction, a perfectly fitted, or an imperfectly fitted valve or bearing?

A. An imperfect one.

Q. How hot can you get water under atmospheric pressure with exhaust steam?

A. 12 degrees.

Q. Does pressure have any influence on the boiling point?

A. Yes.

Q. Which do you think is the best economy, to run with your throttle wide open or partly shut?

A. Always have the throttle wide open on a governor engine.

Q. At what temperature has iron the greatest tensile strength?

A. About 600 degrees.

Q. In what position on the shaft does the eccentric stand in relation to the crank?

A. The throw of the eccentric should always be in advance of the crank pin.

Q. About how many pounds of water are required to yield one horsepower with our best engines?

A. From 25 to 30.

Q. What is meant by atmospheric pressure?

A. The weight of the atmosphere.

Q. What is the weight of atmosphere at sea level?

A. 14.7 pounds.

Q. What is the coal consumption per hour per indicated horsepower?

A. Varies from one and a half to seven pounds.

Q. What is the consumption of coal per hour on a square foot of grate surface?

A. From 10 to 12 pounds.

Q. What is the water consumption in pounds per hour per indicated horsepower?

A. From 25 to 60 pounds.

Q. How many pounds of water can be evaporated with one pound of best soft coal?

A. From 7 to 10 pounds.

Q. How much steam will one cubic inch of water evaporate under atmospheric pressure?

A. One cubic foot of steam (approximately).

Q. What is the weight of a cubic foot of fresh water?

A. Sixty-two and a half pounds.

Q. What is the weight of a cubic foot of iron?

A. 486.6 pounds.

Q. What is the weight of a square foot of one-half inch boiler plate?

A. 20 pounds.

Q. How much wood equals one ton of soft coal for steam purposes?

A. About 4,000 pounds of wood.

Q. How long have you run engines?

Q. Have you ever done your own firing?

Q. What is the source of all power in the steam engine?

A. The heat stored up in the coal.

Q. How is the heat liberated from the coal?

A. By burning it; that is, by combustion.

Q. Of what does coal consist?

A. Carbon, hydrogen, nitrogen, sulphur, oxygen and ash.

Q. What are the relative proportions of these that enter into coal?

A. There are different proportions in different specimens of coal, but the following shows the average per cent: Carbon, 80; hydrogen, 5; nitrogen, 1; sulphur, 2: oxygen, 7; ash, 5.

Q. What must be mixed with coal before it will burn?

A. Atmospheric air.

Q. What is air composed of?

A. It is composed of nitrogen and oxygen in the proportion of 77 of nitrogen to 23 of oxygen.

Q. What parts of the air mix with what parts of the coal?

A. The oxygen of the air mixes with the carbon and hydrogen of the coal.

Q. How much air must mix with the coal?

A. 150 cubic feet of air for every pound of coal.

Q. How many pounds of air are required to burn one pound of carbon?

A. Twelve.

Q. How many pounds of air are required to burn one pound of hydrogen?

A. Thirty-six.

Q. Is hydrogen hotter than carbon?

A. Yes, four and one-half times hotter.

Q. What part of the coal gives out the most heat?

A. The hydrogen does part for part, but as there is so much more of carbon than hydrogen in the coal we get the greatest amount of heat from carbon.

Q. In how many different ways is heat transmitted?

A. Three; by radiation, by conduction and by convection.

Q. If the fire consisted of glowing fuel, show how the heat enters the water and forms steam?

A. The heat from the glowing fuel passes by radiation through the air space above the fuel to the furnace crown. There it passes through the iron of the crown by conduction. There it warms the water resting on the crown, which then rises and parts with its heat to the colder water by conduction till the whole mass of water is heated. Then the heated water rises to the surface and parts with its steam, so a constant circulation of water is maintained by convection.

Q. What does water consist of?

A. Oxygen and hydrogen.

Q. In what proportion?

A. Eight of oxygen to one of hydrogen by weight.

Q. What are the different kinds of heat?

A. Latent heat, sensible heat and sometimes total heat.

Q. What is meant by latent heat?

A. Heat that does not affect the thermometer and which expands itself in changing the nature of a body, such as turning ice into water or water into steam.

Q. Under what circumstances do bodies get latent heat?

A. When they are passing from a solid state to a liquid or from a liquid to a gaseous state.

Q. How can latent heat be recovered?

A. By bringing the body back from a state of gas to a liquid or from that of a liquid to that of a solid.

Q. What is meant by a thermal unit?

A. The heat necessary to raise one pound of water at 39 degrees Fn. 1 degree Fahrenheit.

Q. If the power is in coal, why should we use steam?

A. Because steam has some properties which make it an invaluable agent for applying the energy of the heat to the engine.

Q. What is steam?

A. It is an invisible elastic gas generated from water by the application of heat.

Q. What are its properties which make it so valuable to us?

A. 1.—The ease with which we can condense it. 2.—Its great expansive power. 3.—The small space it occupies when condensed.

Q. Why do you condense the steam?

A. To form a vacuum and so destroy the back pressure that would otherwise be on the piston and thus get more useful work out of the steam.

Q. What is vacuum?

A. A space void of all pressure.

Q. How do you maintain a vacuum?

A. By the steam used being constantly condensed by the cold water or cold tubes, and the air pump as constantly clearing the condenser out.

Q. Why does condensing the used steam form a vacuum?

A. Because a cubic foot of steam, at atmospheric pressure, shrinks into about a cubic inch of water.

Q. What do you understand by the term horse power?

A. A horse power is equivalent to raising 33,000 pounds one foot per minute, or 550 pounds raised one foot per second.

Q. How do you calculate the horse power of tubular or flue boilers?

A. For tubular boilers, multiply the square of the diameter by length, and divide by four. For flue boilers, multiply the diameter by the length and divide by four; or, multiply area of grate surface in square feet by 1½.

Q. What do you understand by lead on an engine's valve?

A. Lead on a valve is the admission of steam into the cylinder before the piston completes its stroke.

Q. What is the clearance of an engine as the term is applied at the present time?

A. Clearance is the space between the cylinder head and the piston head with the ports included.

Q. What are considered the greatest improvements on the stationary engine in the last forty years?

A. The governor, the Corliss valve gear and the triple compound expansion.

Q. What is meant by triple expansion engine?

A. A triple expansion engine has three cylinders using the steam expansively in each one.

Q. What is a condenser as applied to an engine?

A. The condenser is a part of the low pressure engine and is a receptacle into which the exhaust enters and is there condensed.

Q. What are the principles which distinguish a high pressure from a low pressure engine?

A. Where no condenser is used and the exhaust steam is open to the atmosphere.

Q. About how much gain is there by using the condenser?

A. 17 to 25 per cent where cost of water is not figured.

Q. What do you understand by the use of steam expansively?

A. Where steam admitted at a certain pressure is cut off and allowed to expand to a lower pressure.

Q. How many inches of vacuum give the best results in a condensing engine?

A. Usually considered 25.

Q. What is meant by a horizontal tandem engine?

A. One cylinder being behind the other with two pistons on same rod.

Q. What is a Corliss valve gear?

A. *(Describe the half moon or crab claw gear, or oval arm gear with dash pots.)*

Q. From what cause do belts have the power to drive shafting?

A. By friction or cohesion.

Q. What do you understand by lap?

A. Outside lap is that portion of valve which extends beyond the ports when valve is placed on the center of travel, and inside lap is that portion of valve which projects over the ports on the inside or towards the middle of valve.

Q. What is the use of lap?

A. To give the engine compression.

Q. Where is the dead center of an engine?

A. The point where the crank and the piston rod are in the same right line.

Q. What is the tensile strength of American boiler iron?

A. 40,000 to 60,000 pounds per square inch.

Q. What is very high tensile strength in boiler iron apt to go with?

A. Lack of homogeneousness and lack of toughness.

Q. What is the advantage of toughness in boiler plate?

A. It stands irregular strains and sudden shocks better.

Q. What are the principal defects found in boiler iron?

A. Imperfect welding, brittleness, low ductility.

Q. What are the advantages of steel as a material for boiler plates?

A. Homogeneity, tensile strength, malleability, ductility and freedom from laminations and blisters.

Q. What are the disadvantages of steel as a material for boiler plates?

A. It requires greater skill in working than iron, and has, as bad qualities, brittleness, low ductility and flaws induced by the pressure of gas bubbles in the ingot.

Q. When would you oil an engine?

A. Before starting it and as often while running as necessary.

Q. How do you find proper size of any stay bolts for a well made boiler?

A. First, multiply the given steam pressure per square inch by the square of the distance between centers of stay bolts, and divide the product by 6,000, and call the answer "the quotient." Second, divide "the quotient" by .7854, and extract the square root of the last quotient; the answer will give the required diameter of stay bolts at the bottom of thread.

Q. In what position would you place an engine, to take up any slack motion of the reciprocating parts?

A. Place engine in the position where the least wear takes place on the journals. That is, in taking up the wear of the crank-pin brasses, place the engine on either dead center, as, when running, there is but little wear upon the crank-pin at these points. If taking up the cross-head pin brasses—without disconnecting and swinging the rod—place the engine at half stroke, which is the extreme point of swing of the rod, there being the least wear on the brasses and cross-head pin in this position.

Q. What benefits are derived by using flywheels on steam engines?

A. The energy developed in the cylinder while the steam is doing its work is stored up in the flywheel, and given out by it while there is no work being done in the cylinder—that is, when the engine is passing the dead centers. This tends to keep the speed of the engine shaft steady.

Q. Name several kinds of reducing motions, as used in indicator practice?

A. The pantograph, the pendulum, the brumbo pulley, the reducing wheel.

Q. How can an engineer tell from an indicator diagram whether the piston or valves are leaking?

A. Leaky steam valves will cause the expansion curve to become convex; that is, it will not follow hyperbolic expansion, and will also show increased back pressure. But if the exhaust valves leak also, one may offset the other, and the indicator diagram would show no leak.

A leaky piston can be detected by a rapid falling in the pressure on the expansion curve immediately after the point of cut-off. It will also show increased back pressure.

A falling in pressure in the upper portion of the compression curve shows a leak in the exhaust valve.

Q. What would be the best method of treating a badly scaled boiler, that was to be cleaned by a liberal use of compound?

A. First open the boiler up and note where the loose scale, if any, has lodged. Wash out thoroughly and put in the required amount of compound. While the boiler is in service, open the blow-off valve for a few seconds, two or three times a day, to be assured that it does not become stopped up with scale.

After running the boiler for a week, shut it down, and, when the pressure is down and the boiler cooled off, run the water out and take off the hand-hole plates. Note what effect the compound has had on the scale, and where the disengaged scale has lodged. Wash out thoroughly and use judgment as to whether it is advisable to use a less or greater quantity of compound, or to add a small quantity daily.

Continue the washing out at short intervals, as many boilers have been burned by large quantities of scale dropping on the crown sheets and not being removed.

Q. If a condenser was attached to a side-valve engine, that had been set to run non-condensing, what changes, if any, would be necessary?

A. More lap would have to be added to the valve to cut off the steam at an earlier point of the stroke; if not, the initial pressure into the cylinder would be throttled down and the economy, to be gained from running condensing, lessened.

Q. If you are carrying a vacuum equal to 27½ inches of mercury, what should the temperature of the water in the hot well be?

A. 108 degrees Fahrenheit.

Q. Define specific gravity.

A. The specific gravity of a substance is the number which expresses the relation between the weights of equal volume of that substance, and distilled water of 60 degrees Fahrenheit.

Q. Find the specific gravity of a body whose volume is 12 cubic inches, and which floats in water with 7 cubic inches immersed.

A. When a body floats in water, it displaces a quantity of water equal to the weight of the floating body. Thus, if a body of 12 cubic inches in volume floats with 7 cubic inches immersed, 7 cubic inches of water must be equal in weight to 12 cubic inches of the substance and one cubic inch of water to twelve-sevenths cubic inches of the substance.

As specific gravity equals weight of one volume of substance divided by weight of equal volume of water, then specific gravity of the substance in this case equals 1 divided by twelve-sevenths.

USEFUL INFORMATION.

To find circumference of a circle, multiply diameter by 3.1416.

To find diameter of a circle, multiply circumference by .31831.

To find area of a circle multiply square of diameter by .7854.

To find area of a triangle, multiply base by one-half the perpendicular height.

To find surface of a ball, multiply square of diameter by 3.1416.

To find solidity of a sphere, multiply cube of diameter by .5236.

To find side of an equal square, multiply diameter by .8862.

To find cubic inches in a ball multiply cube of diameter by .5236.

Doubling the diameter of a pipe increases its capacity four times.

A gallon of water (U. S. standard) weighs 8 1-3 pounds and contains 231 cubic inches.

A cubic foot of water contains 7½ gallons, 1728 cubic inches, and weighs 62½ pounds.

To find the pressure in pounds per square inch of a column of water multiply the height of the column in feet by .434.

Steam rising from water at its boiling point (212 degrees) has a pressure equal to the atmosphere (14.7 pounds to the square inch).

A standard horse power: The evaporation of 30 lbs. of water per hour from a feed water temperature of 100 degrees F. into steam at 70 lbs. gauge pressure.

To find capacity of tanks any size; given dimensions of a cylinder in inches, to find its capacity in U. S. gallons: Square the diameter, multiply by the length and by .0034.

To ascertain heating surface in tubular boilers, multiply two-thirds of the circumference of boiler by length of boiler in inches and add to it the area of all the tubes.

One-sixth of tensile strength of plate multiplied by thickness of plate and divided by one-half the diameter of boiler gives safe working pressure for tubular boilers. For marine boilers add 20 per cent for drilled holes.

To find the horsepower of an engine, the following four factors must be considered: Mean effective or average pressure on the cylinder, length of stroke, diameter of cylinder, and number of revolutions per minute. Find the area of the piston in square inches by m plying the diameter by 3.1416 and multiply the by the steam pressure in pounds per square inch tiply this product by twice the product of the length of the stroke in feet and the number of revolutions per minute; divide the result by 33,000, and the result will be the horsepower of the engine.

(Theoretically a horsepower is a power that will raise 33,000 pounds one foot in one minute.)

The power of fuel is measured theoretically from the following basis: If a pound weight fall 780 feet in a vacuum, it will generate heat enough to raise the temperature of one pound of water one degree. Conversely, power that will raise one pound of water one degree in temperature will raise a one pound weight 780 feet. The heat force required to turn a pound of water at 32 degrees into steam would lift a ton weight 400 feet high, or develop two-fifths of one horsepower for an hour. The best farm engine practically uses 35 pounds of water per horsepower per hour, showing that one pound of water would develop only one-thirty-fifth of a horsepower in an hour, or 7 1-7 per cent of the heat force liberated. The rest of the heat force is lost in various ways, as explained in the body of this book.

The following* will assist in determining the amount of power supplied to an engine:

"For instance, a 1 inch belt of the standard grade with the proper tension, neither too tight or too loose, running at a maximum speed of 800 feet a minute will transmit one horsepower, running 1,600 feet two horsepower and 2,400 feet three horsepower. A 2-inch belt at the same speed, twice the power.

"Now if you know the circumference of your flywheel, the number of revolutions your engine is making and the width of belt, you can figure very nearly the amount of power you can supply without slipping your belt. For instance, we will say your flywheel is 40 inches in diameter or 10.5 feet nearly in circumference and your engine was running 225 revolutions a minute, your belt would be traveling 225x10.5 feet = 2362.5 feet, or very nearly 2,400 feet, and if one inch of belt would transmit three horsepower running this speed, a 6-inch belt would transmit eighteen horsepower, a 7-inch belt twenty-one horsepower, an 8-inch belt twenty-four horsepower, and so on. With the above as a basis for figuring you can satisfy yourself as to the power you are furnishing. To get the best results a belt wants to sag slightly, as it hugs the pulley closer, and will last much longer."

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*J. H. Maggard in "Rough and Tumble Engineering."

KEYING PULLEYS.*

A key must be of equal width its whole length and accurately fit the seats on shaft and in pulley. The thickness should vary enough to make the taper correspond with that of the seat in the pulley. The keys should be driven in tight enough to be safe against working loose. The hubs of most of the pulleys on the machine run against the boxes, and in keying these on, about 1-32 of an inch end play to the shaft should be allowed, because there is danger of the pulley rubbing so hard against the end of the box as to cause it to heat.

A key that is too thin but otherwise fits all right can be made tight by putting a strip of tin between the key and the bottom of the seat in the pulley.

Drawing Keys. If a part of the key stands outside of the hub, catch it with a pair of horseshoe pinchers and pry with them against the hub, at the same time hitting the hub with a hammer so as to drive pulley on. A key can sometimes be drawn by catching the end of it with a claw hammer and driving on the hub of pulley. If pulley is against box and key cut off flush with hub, take the shaft out and use a drift from the inside, or if seat is not long enough to make this possible, drive the pulley on until the key loosens.

BABBITTING BOXES.*

To babbitt any kind of a box, first chip out all of the old babbitt and clean the shaft and box thoroughly with benzine. This is necessary or gas will be formed from the grease when the hot metal is poured in and leave "blow holes." In babbitting a *solid box* cover the shaft with paper, draw it smooth and tight, and fasten the lapped ends with mucilage. If this is not done the shrinkage of the metal in cooling will make it fast on the shaft, so that it can't be moved. If this happened it would be necessary to put the shaft and box together in the fire and melt the babbitt out or else break the box to get it off. Paper around the shaft will prevent this and if taken out when the babbitt has cooled the shaft will be found to be just tight enough to run well.

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*Courtesy J. I. Case Threshing Machine Co., from "Science of Successful Threshing."

Before pouring the box, block up the shaft until it is in line and in center of the box and put stiff putty around the shaft and against the ends of the box to keep the babbitt from running out. Be sure to leave air-holes at each end at the top, making a little funnel of putty around each. Also make a larger funnel around the pouring hole, or, if there is none, enlarge one of the air-holes at the end and pour in that. The metal should be heated until it is just hot enough to run freely and the fire should not be too far away. When ready to pour the box, don't hesitate or stop, but pour continuously and rapidly until the metal appears at the air holes. The oil hole may be stopped with a wooden plug and if this plug extends through far enough to touch the shaft, it will leave a hole through the babbitt so that it will not be necessary to drill one.

A split box is babbitted in the same manner except that strips of cardboard or sheet-iron are placed between the two halves of the box and against the shaft to divide the babbitt. To let the babbitt run from the upper half to the lower, cut four or six V-shaped notches, a quarter of an inch deep, in the edges of the sheet-iron or cardboard that come against the shaft. Cover the shaft with paper and put cardboard liners between the box to allow for adjustment as it wears. Bolt the cap on securely before pouring. When the babbitt has cooled, break the box apart by driving a cold chisel between the two halves. Trim off the sharp edges of the babbitt and with a round-nose chisel cut oil grooves from the oil hole towards the ends of the box and on the slack side of the box or the one opposite to the direction in which the belt pulls.

The ladle should hold six or eight pounds of metal. If much larger it is awkward to handle and if too small it will not keep the metal hot long enough to pour a good box. The cylinder boxes on the separator take from two to three pounds of metal each. If no putty is at hand, clay mixed to the proper consistency may be used. Use the best babbitt you can get for the cylinder boxes. If not sure of the quality, use ordinary zinc. It is not expensive and is generally satisfactory.

MISCELLANEOUS.

Lime may be taken out of an injector by soaking it over night in a mixture of one part of muriatic acid and ten parts soft water. If a larger proportion of acid is used it is likely to spoil the injector.

A good blacking for boilers and smokestacks is asphaltum dissolved in turpentine.

To polish brass, dissolve 5 cents' worth of oxalic acid in a pint of water and use to clean the brass. When tarnish has been removed, dry and polish with chalk or whiting.

It is said that iron or steel will not rust if it is placed for a few minutes in a warm solution of washing soda.

Grease on the bottom of a boiler will stick there and prevent the water from conducting away the heat. When steel is thus covered with grease it will soon melt in a hot fire, causing a boiler to burst if the steel is poor, or warping it out of shape if the steel is good.

Sulphate of lime in water, causing scale, may be counteracted and scale removed by using coal oil and sal soda. When water contains carbonate of lime, molasses will remove the scale.

CODE OF WHISTLE SIGNALS.

One short sound means to stop.

Two short sounds means the engine is about to begin work.

Three medium short sounds mean that the machine will soon need grain and grain haulers should hurry.

One rather long sound followed by three short ones means the water is low and water hauler should h

A succession of short, quick whistles means distress or fire.

WEIGHT PER BUSHEL OF GRAIN.

The following table gives the number of pounds per bushel required by law or custom in the sale of grain in the several states:

	Barley.	Beans.	Buckwheat.	Clover.	Flax.	Millet.	Oats.	Rye.	Shelled Corn	Timothy.	Wheat.
Arkansas	48	60	52	60	..	..	..	56	56	45	60
California	50	..	40	..	..	..	32	54	52	..	60
Connecticut	..	..	45	..	..	..	32	56	56	..	56
District of Columbia	47	62	48	60	..	..	32	56	56	45	60
Georgia	40	..	..	60	..	..	35	56	56	45	60
Illinois	48	60	52	60	56	45	32	56	56	..	60
Indiana	48	60	50	60	..	..	32	56	56	45	60
Iowa	48	60	52	60	56	48	32	56	56	45	60
Kansas	50	60	50	..	..	..	32	56	56	45	60
Kentucky	48	60	52	60	56	..	32	56	56	45	60
Louisiana	32	..	..	..	..	..	32	..	56	..	60
Maine	48	64	48	..	..	..	30	..	56	..	60
Manitoba	48	..	48	60	56	34	..	56	56	..	60
Maryland	48	64	48	..	..	..	32	56	56	45	60
Massachusetts	48	48	..	..	..	..	32	56	56	..	60
Michigan	48	..	48	60	56	..	32	56	56	45	60
Minnesota	48	60	42	60	..	48	32	56	56	..	60
Missouri	48	60	52	60	56	50	32	56	56	45	60
Nebraska	48	60	52	60	..	..	34	56	56	45	60
New York	48	62	48	60	..	..	32	56	58	44	60
New Jersey	48	..	50	64	..	..	30	56	56	..	60
New Hampshire	..	60	..	..	..	..	30	56	56	..	60
North Carolina	48	..	50	64	..	..	30	56	54	..	60
North Dakota	48	..	42	60	56	..	32	56	56	..	60
Ohio	48	60	50	60	..	..	32	50	56	45	60
Oklahoma	48	..	42	60	56	..	32	56	56	..	60
Oregon	46	..	42	60	..	..	36	56	56	..	60
Pennsylvania	47	..	48	62	..	..	30	56	56	..	60
South Dakota	48	..	52	60	56	50	32	56	56	..	60
South Carolina	48	60	56	60	..	..	33	56	56	..	60
Vermont	48	64	48	..	60	..	32	56	56	42	60
Virginia	48	60	48	64	..	..	32	56	56	45	60
West Virginia	48	60	52	60	..	..	32	56	56	45	60
Wisconsin	48	..	48	60	..	..	32	56	56	..	60

CHAPTER XVI.

DIFFERENT MAKES OF TRACTION ENGINES.

J. I. CASE TRACTION ENGINES.

These engines are among the simplest and at the same time most substantial and durable traction engines on the market. They are built of the best materials throughout, and are one of the easiest engines for a novice to run.

They are of the side crank type, with spring mounting. The engine is supported by a bracket bolted to the side of the boiler, and a pillow block bearing at the firebox end bolted to the side plate of the boiler.

The valve is the improved Woolf, a single simple valve being used, worked by a single eccentric. The eccentric strap has an extended arm pivoted in a wooden block sliding in a guide. The direction of this guide can be so changed by the reverse lever as to vary the cut-off and easily reverse the engine when desired.

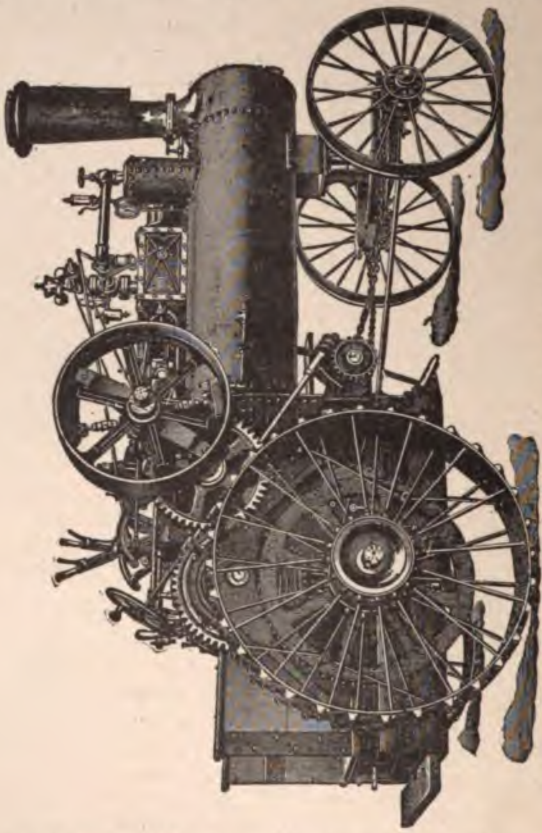
The engine is built either with a simple cylinder or with a tandem compound cylinder.

In the operation of the differential gear, the power is first transmitted to spur gear, containing cushion springs, from thence by the springs to a center ring and four bevel pinions which bear equally upon both bevel gears. The whole differential consequently will move together as but one wheel when engine is moving straight forward or backward; but when turning a corner the four pinions revolve in the bevel gears just in proportion to the sharpness of the curve.

There is a friction clutch working on the inside of the flywheel by means of two friction shoes that can be adjusted as they wear.

There is a feed water heater with three tubes in a watertight cylinder into which the exhaust steam is admitted. The three tubes have smaller pipes inside so that the feed water in passing through forms a thin cylindrical ring.

The traction wheels are driven from the rims. The front wheels have a square band on the center of the rim, to prevent slipping sidewise. The smokestack is cast iron in one piece.

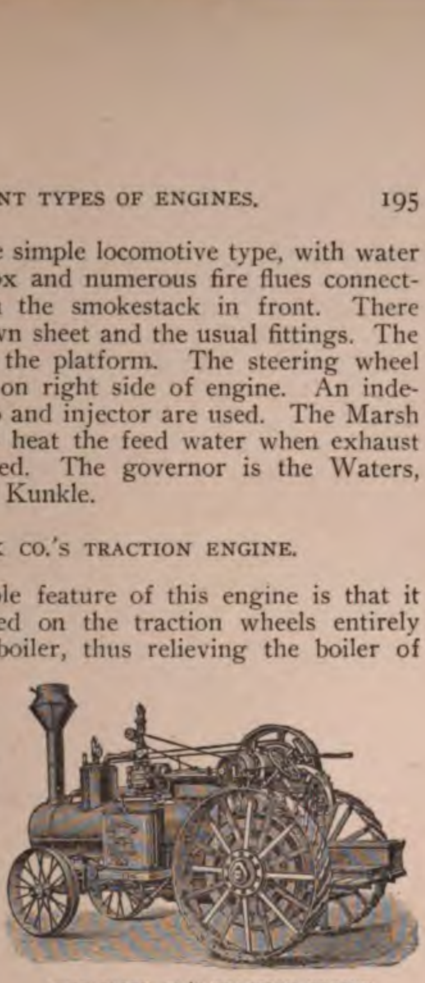


J. I. CASE TRACTION ENGINE.

The firebox will burn wood, coal or straw, a fire brick arch being used for straw, making this fuel give a uniform heat.

The boiler is of the simple locomotive type, with water leg around the firebox and numerous fire flues connecting the firebox with the smokestack in front. There is safety plug in crown sheet and the usual fittings. The water tank is under the platform. The steering wheel and band wheel are on right side of engine. An independent Marsh pump and injector are used. The Marsh pump is arranged to heat the feed water when exhaust heater cannot be used. The governor is the Waters, the safety valve the Kunkle.

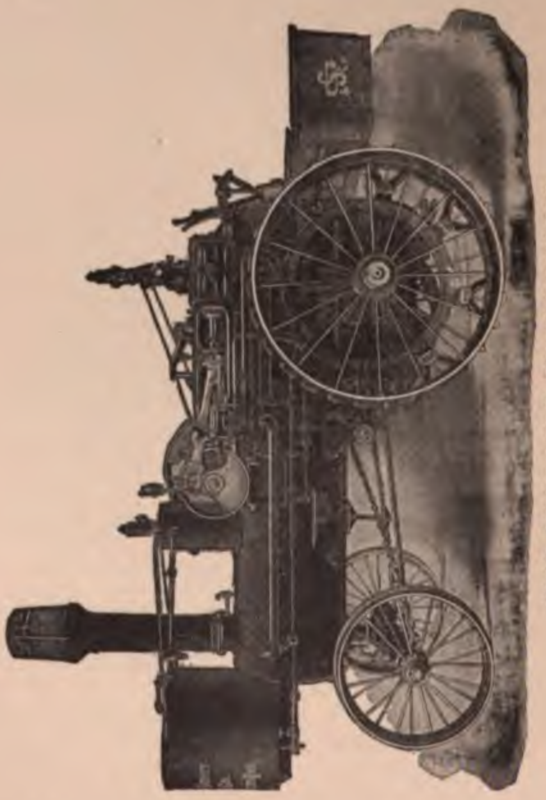
THE FRICK CO.'S TRACTION ENGINE.


THE FRICK CO.'S TRACTION ENGINE.

The most noticeable feature of this engine is that it has a frame mounted on the traction wheels entirely independent of the boiler, thus relieving the boiler of all strain. This is an undeniable advantage, since usually the strain on the boiler is great enough without forcing the boiler to carry the engine and gears.

The gearing to the traction wheels is simple and direct, and a patent elastic spring or cushion connection is used which avoids sudden strain and possible breakage of gears. Steel traction wheels and riveted spokes. Differential gear in main axle, with locking device when both traction wheels are required to pull out of a hole. The reverse gear is single eccentric, the eccentric turning on the shaft. It is well adapted to using steam expansively. The crown sheet is so arranged as not to be left bare of water in going up or down hills. Working parts are covered dust proof. Engine has self-oiling features and sight feed lubricator. Friction clutch in flywheel. Safety brake on main axle. Engineer's platform mounted on springs and every part of engine requiring attention can be reached conveniently from platform.

Crank is center type. Cross-head pump is used. Usual fittings.



GAAR, SCOTT & CO.'S TRACTION ENGINE.

These engines are built with boiler of locomotive type for burning wood and coal, and of return flue type for burning straw. They are also built of three general types, "Corliss-pattern" frame, "Standard" and "Compound."

The engine is side crank, mounted on brackets attached to the sides of the boiler. The bedplate, cylinder and guides are bored at one operation and cannot get out of alignment. Cylinder has wide ports and free exhaust, and piston has self-setting rings. The genuine link reverse gear is used, as on locomotives, and it undoubtedly has many advantages over any other, including an easily adjustable variable cut-off by correct setting of reverse lever.

The differential gear is heavy and effective. A patent steering attachment, with spiral roll, holds chains taut and gives positive motion. Friction clutch is mounted on engine shaft and connects with the hub of the pinion on this shaft. Rigid pinion is also provided. Cross-head pump and injector are used, and Pickering governor with improved spring speeder, permitting quick and easy change of speed; also Sawyer's lever for testing safety. Steam passes direct from dome to cylinder, without loss from cooling or condensing. The steel water tank can be filled by a jet pump operated by steam.

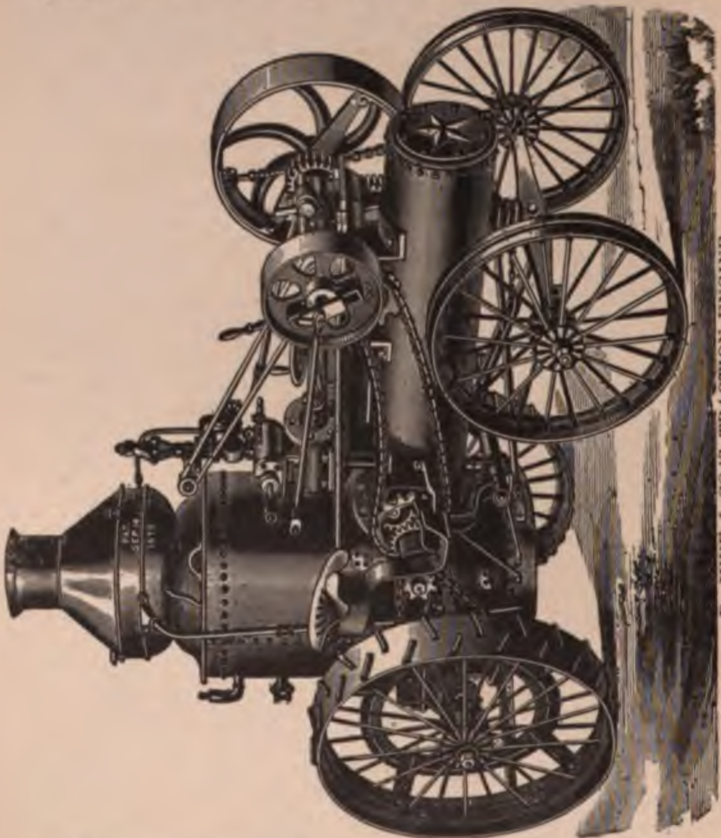
D. JUNE & CO.'S TRACTION ENGINE.

This is one of the very few traction engines built with upright boiler, but it has been on the market many years and has been widely used with great success as a general road locomotive.

The engine is mounted on the water tank. The weight of the boiler comes on the hind wheels, and makes this type of engine superior for pulling. It is claimed that it has no equal on the market as a puller. The upright type of boiler has the advantage that the crown sheet is never exposed and it is claimed flues will last longer than in horizontal type. It works equally well whether it stands level or not, an advantage that no other type has.

This type gets up steam more quickly than any other—it is said, from cold water, in twenty minutes. The steam is superheated in a way to economize fuel and water.

By being mounted on the tank, the engine does not get hot as it would if mounted on the boiler, and the corresponding straining of parts is avoided. A patent water spark arrester is used which is an absolute protection.



D. JUNE & CO.'S TRACTION ENGINE.

The engine is geared to the traction by a chain, which can easily be repaired as the links wear. The friction clutch works inside flywheel. Engine has a new reversible eccentric, and differential gear, with usual fittings.

NICHOLS & SHEPARD TRACTION ENGINE.

The builders of this engine lay special stress upon the care with which the boiler and similar parts are constructed. The important seams are double riveted, and the flue sheet is half inch steel, drilled instead of punched for the flues, and fitted with seamless steel flues, all of the best steel.

NICHOLS & SHEPARD TRACTION ENGINE.

The boiler is the direct flue locomotive type. The crown sheet slopes backward to allow it to be covered with water in descending hills. Boiler has round-bottom firebox. Axle passes around below the boiler, and springs are provided.

The engine is mounted on a long heater, which is attached to the side of the boiler. The locomotive link reverse is used, with a plain slide valve.

Cross-head pump and injector are used, and improved pop safety valve. Cylinder is jacketed, and cross-head guides are rigid with cylinder, so that perfect alignment is always secured.

Engines are built to burn coal or wood. A straw burner is provided with firebrick arch. Compound engines are also built.

THE HUBER TRACTION ENGINE.

The Huber boiler is of the return flue type, and the gates are in the large central tube. This does away with the low-hanging firebox, and enables the engine to cross streams and straddle stumps as the low firebox type cannot do. The cylindrical shape of the boiler also adds considerably to its strength. The water tank is carried in front, and swings around so as to open the smoke box, so that repairs may be made on the fire tubes at this end easily in the open air. With water front return flue boilers the workman has to crawl through entire length of central flue. As there is no firebox, the boiler is mounted above the axle, not by bolting a plate to the side of the firebox. The boiler is made fast to the axle, which is mounted on wheels with spring cushion gear, the springs being placed in the wheel itself, between the two bearings

THE HUBER TRACTION ENGINE.

of the wheel or the hub on trunnions, which form the spindle for the hub. The wheel revolves on the trunnion instead of on the axle, and there is no wear on the axle. The traction gear has a spring connection so that in starting a load there is little danger of breakage. The compensating gear is all spur. The intermediate gear has a ten-inch bearing, with an eccentric in the center for adjusting the gear above and below. There is a spring draw bar and elastic steering device. An improved friction clutch works on inside of flywheel. Engine has a special governor adapted to varying work over rough roads, etc.

A single eccentric reverse gear is used, with arm and wood slide block (Woolf); and there is a variable exhaust, by which a strong draft may be quickly created by shutting off one of two exhaust nozzles. When both exhausts are open, back pressure is almost entirely relieved.

The steam is carried in a pipe down through the middle of the central flue, so that superheating is secured, which it is claimed makes a saving of over 8 per cent in fuel and water. The stack is double walled with air space between the walls.

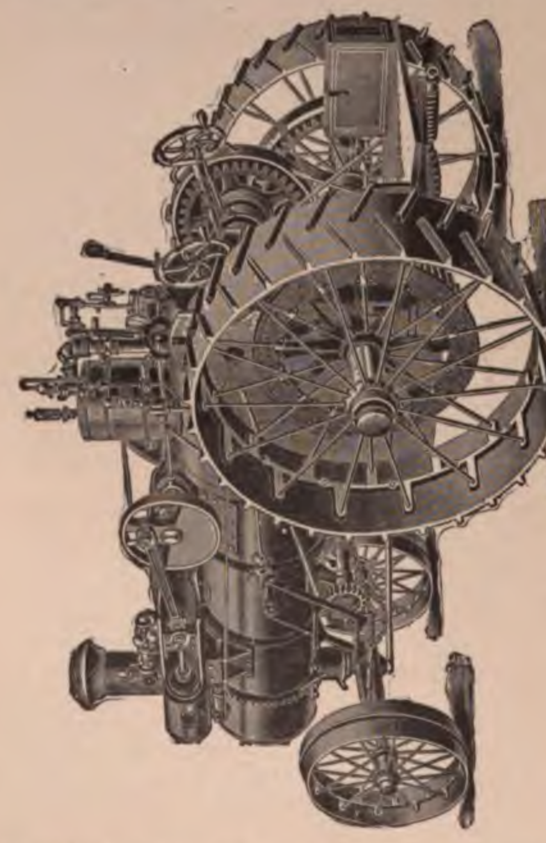
A special straw-burning engine is constructed with a firebox extension in front, and straw passes over the end of a grate in such a way as to get perfect combustion. This make of engine is peculiarly adapted to burning straw successfully.

A. W. STEVENS' TRACTION ENGINE.

This engine has locomotive pattern boiler, with sloping crown sheet, and especially high offset over firebox, doubling steam space that will give dry steam at all times. A large size steam pipe passes from dome in rear through boiler to engine in front, superheating steam and avoiding condensation from exposure. Grate is a rocking one, easily cleaned and requiring little attention, and firedoor is of a pattern that remains air-tight and need seldom be opened.

The engine is mounted upon the boiler, arranged for rear gear traction attachment. Engine frame, cylinder, guides, etc., are cast in one solid piece.

It has a special patented single eccentric reverse, and



A. W. STEVENS' TRACTION ENGINE.

Pickering horizontal governor. There is a friction clutch, Marsh steam pump, and injector. Other fittings are complete, and engine is well made throughout.

AULTMAN-TAYLOR TRACTION ENGINE.

The Aultman-Taylor Traction Engine is an exceptionally well made engine of the simplest type, and has been on the market over 25 years. There are two general types, the wood and coal burners with locomotive boilers, and return flue boiler style for burning straw. A compound engine is also made with the Woolf single valve gear.

A special feature of this engine is that the rear axle comes behind the firebox instead of between the firebox and the front wheels. This distributes the weight of the engine more evenly. The makers do not believe in springs for the rear axle, since they have a tendency to wear the gear convex or round, and really accomplish much less than they are supposed to.

AULTMAN-TAYLOR TRACTION ENGINE.

Another special point is the bevel traction gear. The engine is mounted on the boiler well toward the front, and the flywheel is near the stack (in the locomotive type). By bevel gears and a long shaft the power is conducted to the differential gear in connection with the rear wheels. The makers claim that lost motion can be taken up in a bevel gear much better than in a spur gear. Besides, the spur gear is noisy and not nearly so durable. Much less friction is claimed for this type of gear.

The governor is the Pickering; cross-head pump is used, with U. S. injector, heater, and other fittings complete. A band friction clutch is used, said to be very durable. Diamond special spark arrester is used except in straw burners. The platform and front bolster are provided with springs. The makers especially recommend their compound engine, claiming a gain of about 25 per cent. The use of automatic band cutters and feeders, automatic weighers and baggers, and pneumatic stackers with threshing machine outfits make additional demands on an engine that is best met by the compound type. With large outfits, making large demands, the compound engine gives the required power without undue weight.

AVERY TRACTION ENGINE.

The Avery is an engine with a return flue boiler and full water front, and also is arranged with a firebox besides. There is no doubt that it effects the greatest economy of fuel possible, and is adaptable equally for wood, coal, or straw. The boiler is so built that a man may readily crawl through the large central flue and get at the front ends of the return tubes to repair them.

AVERY TRACTION ENGINE.

The side gear is used with a crank disc instead of arm. The reverse is the Grime, a single eccentric with device for shifting for reverse. The friction clutch has unusually long shoes, working inside the flywheel, with ample clearance when lever is off. A specialty is made of extra wide traction wheels for soft country. The traction gear is of the spur variety. There is also a double speed device offered as an extra.

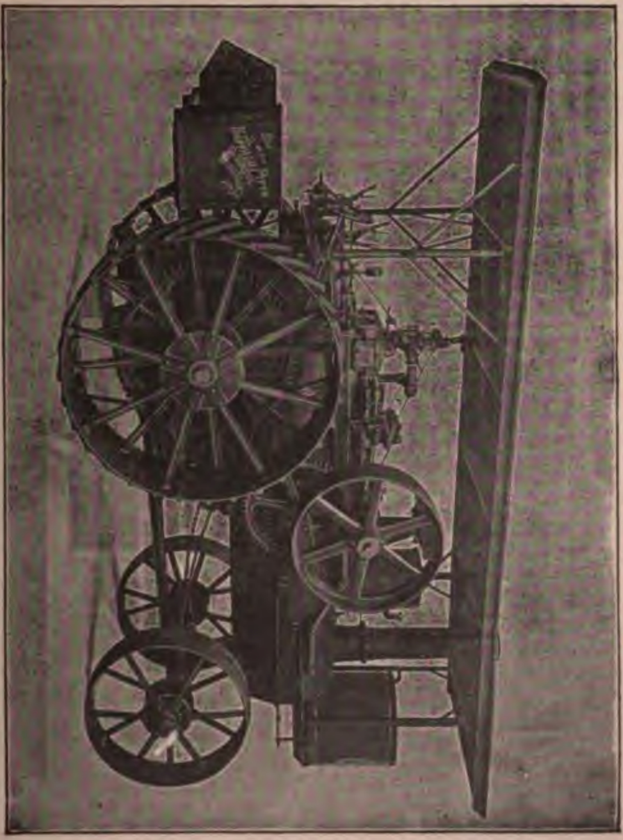
The water tank is carried in front, and lubricator, steering wheel (on same side as band wheel for convenience in lining up with separator), reverse lever, friction clutch, etc.. are all right at the hand of the engineer.

The traction gear is of the spur variety, adjusted to be evenly distributed to both traction wheels through the compensating gear, and to get the best possible pull in case of need.

For pulling qualities and economy of fuel, this engine is especially recommended.

BUFFALO PITTS TRACTION ENGINE.

The Buffalo Pitts Engine is built either single cylinder or double cylinder. The boiler is of the direct flue locomotive type, with full water bottom firebox. The straw burners are provided with a firebrick arch in the firebox. Boilers are fully jacketed.



BUFFALO PITTS TRACTION ENGINE.

The single and double cylinder engines differ only in this one particular, the double cylinder having the advantage of never being on a dead center and starting with perfect smoothness and gently, seldom throwing off belt. The frame has bored guides, in same piece with cylinder, effecting perfect alignment.

The compensating gear is of the bevel type, half shrouded and so close together that sand and grit are kept out. Three pinions are used, which it is claimed prevent rocking caused by two or four pinions.

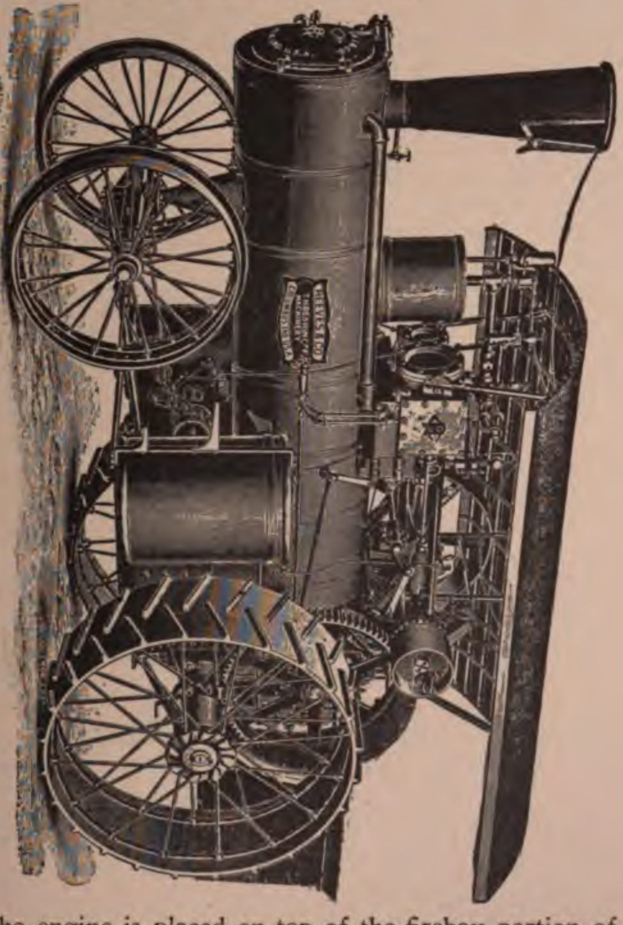
Cross-head has shoes unusually long and wide. The engine frame is of the box pattern, and is also used as a heater, feed water for either injector or steam pump passing through it. Valve is of the plain locomotive slide type.

The friction clutch has hinged arms working into flywheel with but slight beveling on flywheel inner surface, and being susceptible of easy release. It is a specially patented device. The Woolf single eccentric reverse gear is used. Engine is fully provided with all modern fittings and appliances in addition to those mentioned. It was the only traction engine exhibited at Pan-American Exposition which won gold medal or highest award. It claims extra high grade of workmanship and durability.

THE REEVES TRACTION ENGINES.

These engines are made in two styles, simple double cylinder and cross compound. The double cylinder and cross compound style have been very successfully adapted to traction engine purposes with certain advantages that no other style of traction engine has. With two cylinders and two pistons placed side by side, with crank pins at right angles on the shaft, there can be no dead centers, at which an engine will be completely stuck. Then sudden starting is liable to throw off the main belt. With a double cylinder engine the starting is always gradual and easy, and never fails.

The same is equally true of the cross compound, which has the advantage of using the steam expansively in the low pressure cylinder. In case of need the live steam may be introduced into the low pressure cylinder, enormously increasing the pulling power of the engine for an emergency, though the capacity of the boiler does not permit long use of both cylinders in this way.



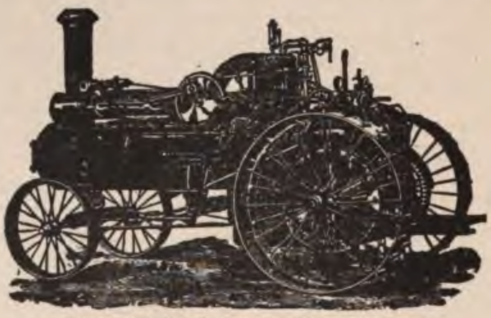
THE REEVES TRACTION ENGINE.

The engine is placed on top of the firebox portion of the boiler, and the weight is nicely balanced so that it comes on both sides alike.

The gearing is attached to the axle and countershaft which extend across the engine. The compensating gear is strong and well covered from dirt. The gearing is the gear type, axle turning with the drivers. There is an independent pump; also injector, and all attachments. The band wheel being on the steering wheel or right side of the engine, makes it easy to line up to a threshing machine. Engine frame is of the Corliss pattern; boiler of locomotive type, and extra strongly built.

THE RUMELY TRACTION ENGINE.

The most striking peculiarity is that the engine is mounted on the boiler differently from most side crank traction engines, the cylinder being forward and the shaft at the rear. This brings the gearing nearer the traction wheels and reduces its weight and complication.



THE RUMELY TRACTION ENGINE.

The boiler is of the round bottom firebox type, with dome in front and an ash pan in lower part of firebox, and is unusually well built and firmly riveted.

The traction wheels are usually high, and the flywheel is between one wheel and the boiler.

The engine frame is of the girder pattern, with overhanging cylinder attached to one end.

The boiler is of the direct flue locomotive type, fitted for straw, wood, or coal. Beam axle of the engine is behind the firebox, and is a single solid steel shaft. Front axle is elliptical, and so stronger than any other type.

A double cylinder engine is now being built as well as the single cylinder. The governor regulates the double cylinder engine more closely than single cylinder types, and in the Rumely is very close to the cut-off where a special simple reverse is used with the double cylinder engine.

Engine is supplied with cross-head pump and injector, Arnold shifting eccentric reverse gear, friction clutch, and large cylindrical water tank on the side. It also has the usual engine and boiler fittings.

PORT HURON TRACTION ENGINE.

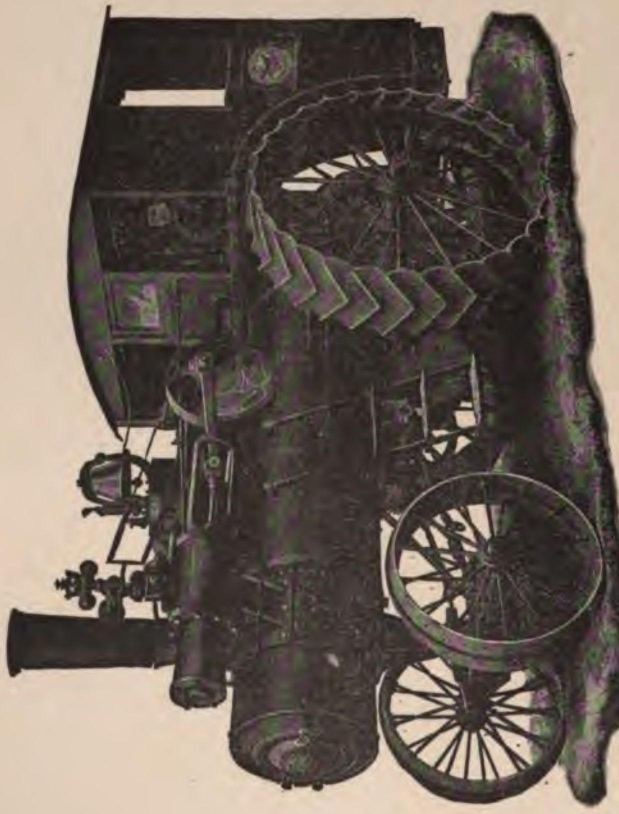
The Port Huron traction engine is of the direct flue locomotive type, built either simple or compound, and of medium weight and excellent proportions for general purpose use. The compound engine (tandem Woolf cylinders) is especially recommended and pushed as more economical than the simple cylinder engine. As live steam can be admitted to the low pressure cylinder, so turning the compound into a simple cylinder engine with two cylinders, enormous power can be obtained at a moment's notice to help out at a difficult point.

Two injectors are furnished with this engine, and the use of the injector is recommended, contrary to the general belief that a pump is more economical. The company contends that the long exhaust pipe causes more back pressure on the cylinder than would be represented by the saving of heat in the heater. However, a cross-head pump and special condensing heater will be furnished if desired.

On the simple engine a piston valve is used, the seat of the valve completely surrounding it and the ports being circular openings, the result, it is claimed, being a balanced valve.

The valve reverse gear is of the Woolf pattern, the engine frame of the girder type, Waters governor, with special patent speed changer, specially balanced crank disc, patent straw burner arrangement for straw burning engines, special patent spark extinguisher, special patent gear lock, and special patents on front axle, drive wheel and loco cab.

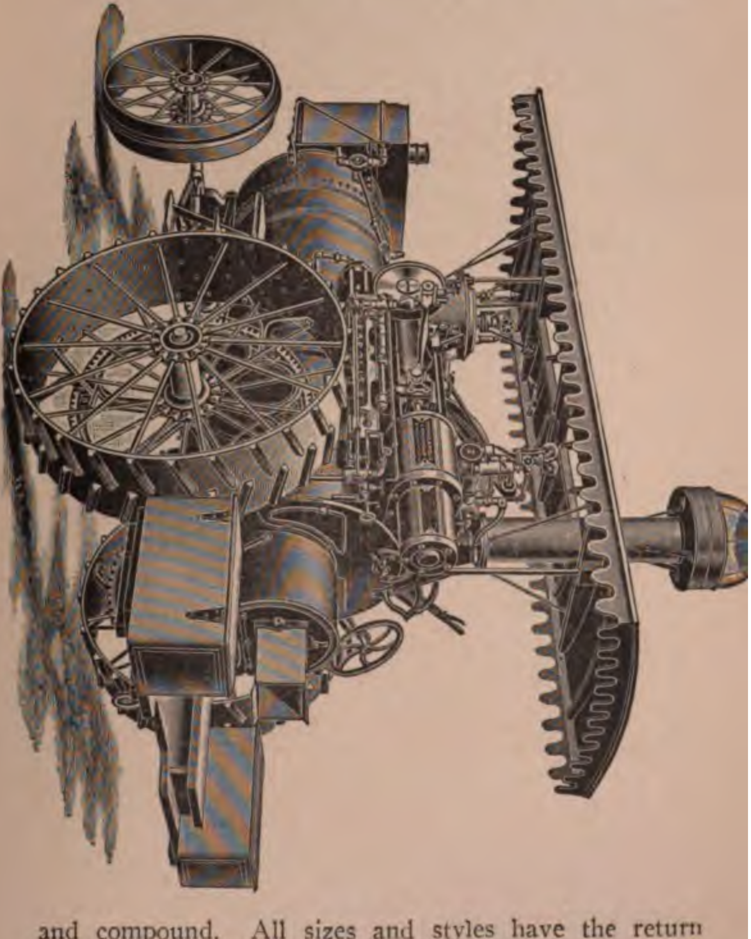
The usual fittings are supplied.



PORT HURON TRACTION ENGINE.

MINNEAPOLIS TRACTION ENGINE.

The Minneapolis traction engine is built both simple and compound. All sizes and styles have the return flue boiler, for wood, coal or straw. Both axles extend entirely and straight under the boiler, giving complete



MINNEAPOLIS TRACTION ENGINE.

support without strain. The cylinder, steam chest and guides form one piece, and are mounted above a heater, secured firmly to the boiler; valve single simple D pattern. Special throttle of the butterfly pattern, large crank pin turned by special device after it is driven in, so insuring perfect adjustment; special patent exhaust nozzle made adjustable and so as always to throw steam in center of stack; friction clutch with three adjustable shoes. Boiler is supplied with a superheater pipe. Woolf valve and reverse gear. Special heavy brass boxes and stuffing-boxes. Sight feed lubricator and needle feed oiler; Gardner spring governor. Complete with usual fittings. This is a simply constructed but very well made engine.

CHAPTER XVII.

ELECTRICITY.

AMMETERS AND VOLTMETERS.

Ammeters for automobile use are constructed on the principle of the D'Arsonval galvanometer with a permanent magnetic field. The special feature is a small oscillating coil mounted on cone-point bearings surrounding a stationary armature which is centrally located between the pole-pieces of a permanent magnet, with a pointer or index-finger which indicates the electrical variations on a graduated scale.

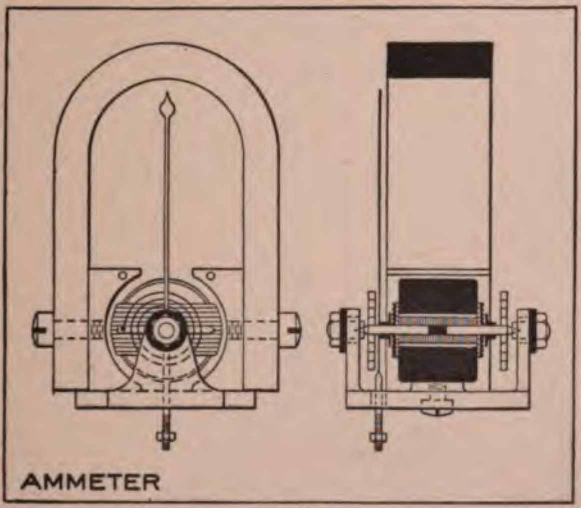


Fig. 65.
CONSTRUCTION OF AMMETER.

The construction of an ammeter is fully shown in the two views in Figure 65. The permanent magnets in its construction are of a special quality of hardened steel, made only for this purpose and possessed of great magnetic permeability. The pole-pieces, which are of soft steel and well annealed, are attached to the inside of the lower part of the magnet legs, the joints between the pole-pieces and the magnet legs are usually ground to insure the full efficiency of the magnetic circuit. The soft iron core of the coil is for the purpose of rendering uniform the magnetic field in which the coil has to oscillate. A coil of insulated wire is wrapped upon the stationary armature at right angles to its axis, that is to say, in the same manner that thread is wound upon a spool, which is short-circuited on itself, that is to say, the ends of the wire forming the coil are fastened together. This coil of wire is for the purpose of choking the magnetism induced in the stationary armature by the oscillating coil, as it generates what are known as eddy currents within itself, thus making the instrument periodic, or dead-beat, in its indications. Around the armature core and outside the short-circuited coil of wire is wound the active or oscillating coil and at right angles to the direction of the winding of the first coil. The oscillating coil consists of a number of turns of fine insulated copper wire, to which the current is conveyed through the medium of the controlling springs at each end of the spindle, which is in two parts and connected together by a suitable sleeve of insulating material, as shown.

The pointer or index-finger is made with a boss or hub to go over the end of the spindle of the active coil and also has an extension with a small counterweight or balance, so that the pointer may be accurately adjusted.

The only difference in the construction of a voltmeter and an ammeter is that in the former the active or oscillating coil is in series with a high resistance, while in the latter it is connected across the terminals of a shunt-block. The voltmeter is in reality an ammeter, the resistance serving to keep the amperage in step with the voltage.

Reference to the three views, marked respectively A, B and C in Figure 66, will show clearly the principle of the operation of an ammeter or voltmeter and the reason that they record the current strength or pressure of an electric current accurately.

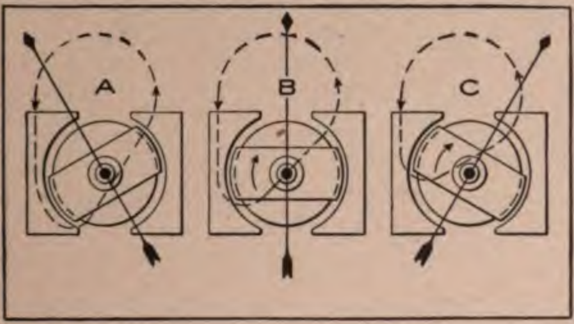


Fig. 66.

DIAGRAM OF AMMETER ARMATURE MOVEMENT.

Ammeters are of two kinds, the double-beat type, as shown in Figure 65, which indicates the current strength or number of amperes flowing in the electric circuit, without any regard to the polarity of the terminals of the circuit, by the pointer or index-finger moving either to the right or to the left of the zero position. The single-beat type of ammeter only records in one direction, by the pointer moving from the left to the right of the graduated scale of the instrument, consequently the polarity of the terminals of this type of ammeter are marked on its outer casing and the polarity of the terminals of the electric circuit must consequently be determined before connecting them with the ammeter.

A volt-ammeter, such as is commonly used on electric automobiles, is shown in Figure 67. This instrument is simply a voltmeter and a double-beat ammeter mounted on a single base and enclosed in a common case, with their graduated scales adjoining each other.

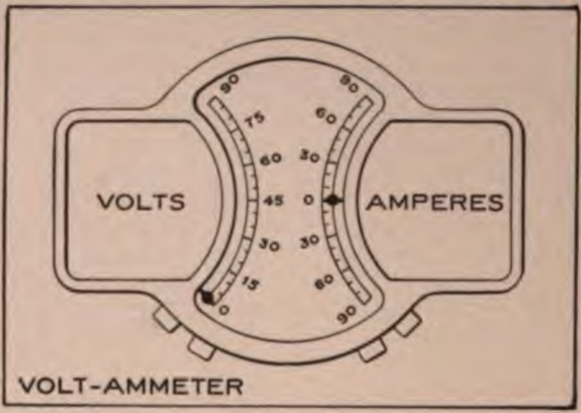


Fig. 67.

AUTOMOBILE VOLT-AMMETER.

ELECTRICAL IGNITION.

There are two methods of producing an electric spark for ignition purposes: The first, by means of an induction coil which has only a single winding, composed of a few layers of insulated copper wire of large size, wound upon a bundle of soft iron wires, known as the core. The second, by the use of an induction coil with a double winding upon its core. The inner winding being composed of a few layers of insulated wire of large size, as in the coil just described, and an outer winding consisting of a great many layers of very small insulated copper wire, in fact, several thousand feet in length.

The coil first described is known as a primary spark coil from the fact that the spark or arc is produced by the direct effect of the battery or generator current flowing in the coil. This form o [illegible] will not arc or jump across a space between two points, but simply occurs between the contact points on the breaking of the contact.

The second form of induction coil is commonly known as a secondary spark coil, because the arc or spark is produced in the secondary winding of the coil, and will jump or arc across a space between two fixed points, without the points first coming in contact.

INDUCTION COIL.

Induction is the process by which a body having electrical or magnetic properties calls forth similar properties in a neighboring body without direct contact. This property is known as self-induction and is caused by the reaction of different parts of the same circuit upon one another, due to variations in distance or current strength. The current produced by an induction coil has a very high electro-motive force and hence great power of overcoming resistance.

The average user of an automobile is well aware that without the battery and the spark coil the motor would not operate. He has learned that, when the spark fails, there are certain forms to be gone through to ascertain the cause of trouble, but as there are other difficulties, it is desirable that more should be known of this important subject.

If a current of electricity be caused to flow through a straight conductor forming a part of a closed electric circuit, lines of force, commonly called magnetic whirls or waves, are induced in the air and rotate around the conductor.

If the current of electricity be flowing in the circuit and through the straight conductor from right to left, as shown in the upper view in Figure 68, the lines of force or magnetic whirls will rotate around the conductor from left to right, or in the direction of the hands of a clock. On the other hand, if the conditions be reversed and the current flows from left to right the lines of force or magnetic whirls will rotate from right to left, as shown in the lower view in Figure 68. The direction of rotation of these lines of force or magnetic whirls may be positively determined by the use of a galvanometer, an electric testing instrument having a needle similar in appearance to that of an ordinary compass. Upon placing this instrument in the path of the lines of force and making and breaking the battery circuit by means of the switch, the needle of the galvanometer will be deflected from its zero point in the direction of the rotation of the lines of force. If the direction of the flow of the electric current through the circuit be changed by reversing the poles of the battery, the needle of the galvanometer will be deflected from its zero point in the opposite direction. Whether these lines of force or magnetic whirls rotate continuously around the wire has not been demonstrated. They rotate with sufficient force to be tested by the galvanometer only until the electric current in the closed circuit has reached its maximum value after closing the circuit: that is to say, only during the infinitesimal space of time required by the current to reach its full value of power.

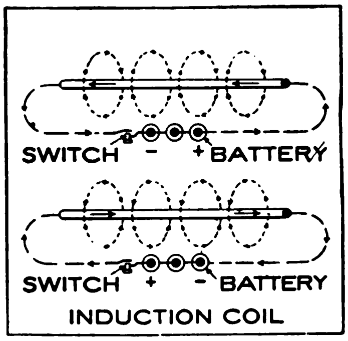


Fig. 68.

MAGNETIC WAVES OR WHIRLS.

If, instead of a straight conductor, a loop of insulated wire, in the form of a circle, be utilized for the passage of the current, as at A and B in Figure 69, the lines of force will still rotate around the wire as shown, their direction being dependent on the direction of the electric current. If the electrical circuit be provided with a current reverser, or device for changing the battery connections in the circuit from positive to negative and vice versa, the lines of force can be made to rotate rapidly first in one direction and then in the other, as indicated in Figure 68.

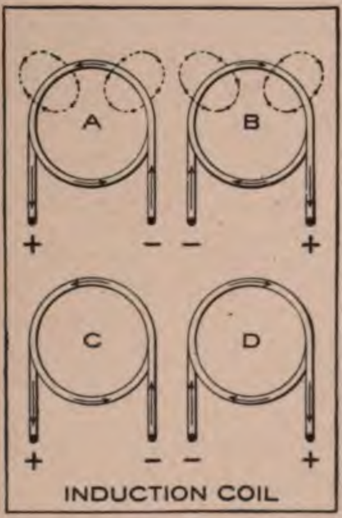


Fig. 69.

MAGNETIC WAVES OR LINES OF FORCE.

Suppose this loop of insulated wire be composed of a great number of turns, it then becomes a coil or closed helix, and as all the lines of force cannot pass between the turns of the electrical conductor forming this helix they must pass completely through the helix instead of rotating around a single loop, as at A and B, Figure 69.

If the current flows through the conductor in the direction indicated by the arrows, at C in Figure 69, and over and around the coil in the direction shown, the lines of force will flow through the coil towards the observer, and complete their path or circuit through the air, returning into the coil at the opposite end. If the current be reversed and flow around the coil in the direction of the hands of a clock, the lines of force will flow through the coil in the opposite direction, that is, away from the observer, as at D, Figure 69.

This form of coil or closed helix may be designated as the primitive form of an electro-magnet. When forming part of a closed electric circuit it possesses the property of magnetizing a bar of wrought iron placed within it. If a short round bar of wrought iron be placed a short distance within the coil and the battery circuit be closed, the iron bar will, if the current is sufficiently strong, be sucked or drawn into the center of the coil, and a considerable effort will be required to withdraw it.

The object of the bundle of soft iron wires, which form the core of any form of spark coil, is to increase the magnetic effect of the lines of force or magnetic flux, or rather to reduce the resistance to their passage through the coil.

As the resistance of air to the flow of the lines of force is about 100,000 times greater than that of wrought iron, the introduction of the iron core into the coil increases its magnetic effect enormously.

As has been previously stated, when a current of electricity flows through a conductor or wire forming a coil or closed helix, lines of force are induced and flow through, and also around the exterior of the coil. In a like manner, when the electric circuit is broken, the lines of force suddenly reverse their direction, and travel through the coil with a tremendous velocity until they reach a state of neutralization. During this reverse travel of the lines of force through the coil, a current of electricity is induced in the winding of the coil, but in the opposite direction to that in which the battery current was flowing. The effect of this induced current, which is of far greater intensity or pressure than the battery current which induced it, is to form an arc or spark at the breaking point in the circuit.

PRIMARY SPARK COIL.

Figure 70 shows a vertical longitudinal section through an induction coil of the form first described, and known as a wipe or touch spark coil. It consists of two principal parts, a core, made of a bundle of soft iron wire, and a coil of wire around this core composed of from 3 to 5 layers of turns of insulated copper wire, varying in diameter from No. 16 to No. 12, B. & S. Gauge, according to the battery conditions under which the coil has to operate. The iron core may vary from three-eights of an inch in diameter and 6 inches long, to three-fourths of an inch in diameter, and 12 to 15 inches long, depending upon the intensity and capacity of the spark required. Reference to the drawing will show that the core A has upon its ends wood or fiber washers D. They may be square or round. Upon the portion of the core between the washers is a paper tube E, upon which the wire forming the primary winding is wound. The ends of the wire forming the coil and shown at P are connected to the binding posts or terminals indicated by the letter T, and located on top of the washers D. The wire B, forming the primary winding, is usually provided with an outer casing, as shown at C, to protect it from water and grease.

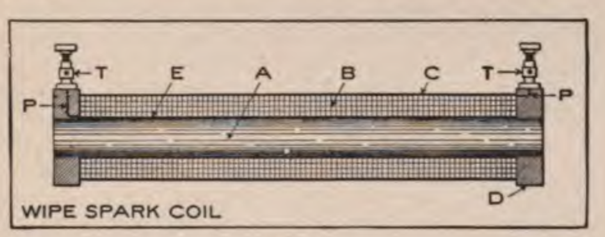


Fig. 70.

PLAIN INDUCTION OR PRIMARY SPARK COIL.

The form of induction coil above described is generally used for ignition purposes on gas and gasoline motors fitted with a mechanical make and break form of spark, which is located within the combustion chamber of the motor itself.

SECONDARY SPARK COIL.

Figure 71 shows the secondary or jump-spark form of coil. It is composed of an iron core and a primary winding similar to that described in conjunction with Figure 70, with the addition of an outer winding of many turns of fine wire. This wire, of very small size, is known as the secondary winding, varying in diameter from No. 36 to No. 40 B. & S. Gauge, and in length from 5,000 to 10,000 feet. In the drawing the induction coil is shown equipped with an electro-magnet make and break or vibrator device, which is the form mostly used for ignition purposes. The other form, known as the plain jump-spark coil, has a mechanically operated make and break device attached to the motor to operate the coil.

The arc or spark produced at the breaking point of the electrical circuit in which the primary winding of the coil is connected is not utilized for ignition purposes in this type of coil. When the circuit is broken the sudden reaction or backward flow of the lines of force or magnetic flux in the iron core produce an induced current in the secondary winding, but in the opposite direction to that of the battery current. This induced current is of so much greater intensity and velocity than that induced in the primary winding by this same reaction, that the arc or spark induced in the secondary winding of the coil will jump across a space from one end of the wire to the other, varying from ⅛ inch to as much as 8 or 10 inches in length, dependent upon the length of wire in the secondary circuit, the electro-motive force of the battery and the frequency of the interruptions or number of times per minute the electric circuit is made and broken.

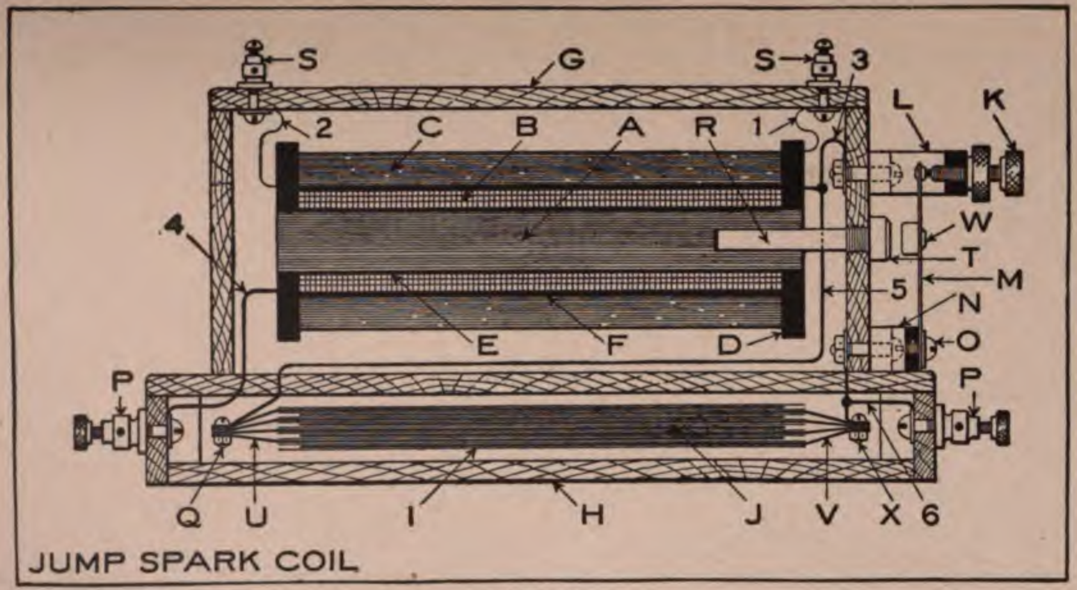


Fig. 71.

SECONDARY OR JUMP-SPARK FORM OF INDUCTION COIL.

In the drawing A is the core, B the primary winding and C the secondary. The two coils are held in place upon the core by the washers D. The primary wire B is wound over a paper tube E, and the secondary wire C is insulated from the primary wire by a mica insulating tube F. The coil proper is enclosed in a wood case G.

The terminals or binding posts on top of the case G are connected with the ends of the secondary wire 1 and 2. The secondary terminals are plainly indicated by the letter S. In the base H of the coil case is the condenser J, an essential feature of this form of coil, which utilizes the induced primary current to produce a greater reactive energy in the secondary winding.

At the right-hand end of the coil and outside the casing G is located the electro-magnetic vibrator or trembling device, which automatically makes and breaks the primary circuit. The end 3 of the primary wire is connected with the contract screw K through the bracket L. The spring M, carried by the bracket N, with screw O, is connected with the terminal or binding post P, immediately beneath it, by the wire 6 through the bracket N. The end 4 of the primary wire is connected with another terminal or binding post P, at the other end of the base of the coil. The condenser J is connected across the contact points of the screw K and the spring M, by the wires 5 and 6 and screws Q and X. The condenser is composed of a number of sheets of tinfoil V, laid between sheets of specially insulated paper I, with the opposite end of every alternate sheet of tinfoil projecting from the paper insulation, as shown. These projecting ends are connected together and by the wires 5 and 6 to the contact screw K and spring M, respectively, as previously described.

When the coil is connected in or forms part of a closed electric circuit by means of the terminal or binding posts P, on the base of the coil, the current flows through the primary winding B. This instantly produces a high degree of magnetism in the core A, and the pole-piece T of the core extension R becomes strongly magnetic and attracts the iron button W of the spring M. This draws the spring M away from the end of the screw K, and in consequence breaks the electric circuit. This results in the demagnetizing of the pole-piece T and the consequent return of the spring M to its normal position in contact with the end of the screw K. So long as the electric circuit remains closed this operation is repeated at a very high rate of speed. The effect of this continuous operation of the coil is to produce an intermittent current in the secondary winding of high intensity and velocity. If wires are placed in the holes in the small terminals or binding posts on the top of the coil and brought within a short distance of each other, a stream of sparks will pass from one wire to the other in a peculiar zigzag manner and emit a loud, crackling noise, accompanied by a peculiar odor, caused by the formation of ozone through the electrochemical action of the spark.

Under ordinary circumstances the arc or spark which occurs on the breaking of the contact between the platinum points of the screw K and spring M would not be utilized, but by means of the condenser in the base, which is connected to these parts, as before described, the static charge of electricity generated by this action is stored in the condenser. When the contact is again made, this stored electric energy is given up or discharged by the condenser and flows through the primary winding of the coil in connection and in the same direction as the battery current and increases the magnetic effect of the core A enormously.

When the coil is used in connection with a gas or gasoline motor a form of ignition device known as a spark plug is used. This is connected with the secondary terminals and screwed into the combustion chamber of the motor A form of circuit breaker upon the motor is used to make and break the electric circuit at the desired point, and the resulting arc or spark inside the combustion chamber ignites the charge of vapor.

This style of coil is sometimes used without the electro-magnetic vibrator, and a mechanical make and break device, actuated by the motor, is used instead, producing as a rule only a single spark.

To remove any doubt as to the origin of the secondary or jump-spark form of induction coil, it may be here briefly stated, that it was invented by Rumkorff in the year 1851, long before the inception of the automobile.

GENERATORS.

This term is usually applied to any form of chemical or mechanical energy which can be used to produce a current of electricity. Mechanical generators of electricity used for ignition purposes are of two forms, dynamos or magnetos. The former is self-exciting by means of coils of wire wound upon the magnet limbs. The latter has permanent magnets instead of coils of wire to induce the current in the armature of the magneto. Magnetos, on account of their simplicity of construction and low first cost, are more generally used for ignition purposes than dynamos. They may be operated by the motor with a friction-pulley, gear or belt. Figure 72 shows one form of a magneto arranged to be operated by the friction pulley on the left-hand end of the armature shaft.

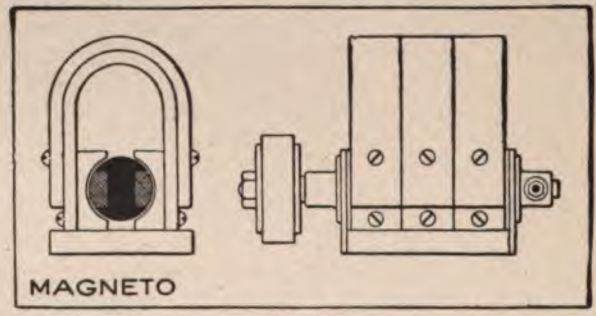


Fig. 72.
MAGNETO GENERATOR WITH SIEMEN'S H TYPE OF ARMATURE.

The simplest form of magneto and the one shown in Figure 72 consists of two or more magnets of horseshoe shape, the ends of which embrace the pole-pieces, between which rotates a shuttle armature wound with small insulated copper wire. Rotation of the armature of the magneto tends to disturb the path of the lines of force or magnetic flux flowing between the ends of the permanent magnets, which in turn set up powerful induced currents in the armature. The current produced by the magneto is of an alternating nature, but converted into a direct or continuous current by means of the commutator on the armature shaft.

STORAGE BATTERIES.

In order that electrical energy may be taken from a storage battery, a current of electricity must first be passed through the battery. A chemical action takes place on the active material of the plates in the cells. During the discharge a reverse chemical action takes place and the plates resume their former condition. Thus it is apparent that a storage battery, if properly made, can be used over and over again, without materially impairing its condition. On account of the chemical changes involved, the whole of the energy required to charge a battery is not available as useful current. Consequently, in determining the size of battery to be used, its efficiency at various rates of charge and discharge must be taken into consideration.

The capacity of a battery depends on the number and size of the plates composing the elements of the cell. Increasing the number of plates increases the capacity, but does not increase the voltage of the cell.

The capacity of a battery is expressed in ampere-hours. As an example, a particular cell will, on discharge, give twenty-five amperes for eight hours, or it has a total capacity of 200 ampere-hours, when discharged at its normal rate of eight hours. If discharged at a higher rate, say five or three hours, the total capacity will be considerably less. For example, the above cell will discharge at the rate of thirty-five amperes for five hours, giving a total capacity of 175 ampere-hours, or it will discharge at the rate of fifty amperes for three hours, giving a total capacity of 150 ampere-hours.

The watt-hour capacity of a battery depends on the density of the electrolyte used. Up to a certain point, the higher the specific gravity of the electrolyte used, the greater will be the capacity. Care should be exercised not to permit the batteries to be discharged too low, or to remain idle for any considerable length of time without being thoroughly re-charged.

The electrolyte used in a storage battery is made up of three to four parts of water to one part pure sulphuric acid. Nothing except distilled water should be used. Freshly caught rain water may be used in case distilled water cannot be obtained. Although it is considerably cheaper, never use commercial sulphuric acid, as it will ruin a battery in a short time, due to the presence of iron in the commercial acid. Chemically pure acid only should be used.

The electrolyte should have a specific gravity of 1.25, this is usually written as 1250. The specific gravity of a solution is determined by the use of a hydrometer, which is an instrument so designed that the zero of its scale is on a level with the surface, when immersed in pure or distilled water. The hydrometer will rise until the 1.25 degree mark is about on a level with the surface, when sufficient acid has been added to raise the specific gravity to 1250. The electrolyte should always cover the top of the plates at least one-half of an inch, and, when fully charged, should be tested every few weeks with the hydrometer.

A storage battery has a normal electromotive force of about two volts and an internal resistance so low as to be negligible in all ordinary calculations, consequently the voltage across the terminals of a number of storage cells in series will be equal to the combined voltage of the individual cells and will in most cases remain practically the same, irrespective of the quantity of current which is flowing from the battery.

A storage battery will work equally well on either an open or closed circuit, it will give out a small or large current continuously or intermittently, and under practically the same voltage.

The voltage of the charging circuit should be at least 20 per cent higher than the voltage of the storage battery. Always use a direct current, as an alternating current cannot be used. If possible, a storage battery should always be charged at its normal charging rate, or preferably at a slower rate, for the slower a storage battery is charged, the greater will be its discharge capacity. The normal charging rate is usually taken to be four to five hours, irrespective of the capacity of the battery. Charge the battery until the voltmeter shows 2.6 volts while the battery is in the charging circuit.

When charging a storage battery, it is of great importance that the connections with the charging circuit be properly arranged. That is, the positive pole of the circuit should always be connected to the positive pole of the storage battery.

Sometimes it is desirable to charge a battery quickly, in order to save time, when far from home with an electric car whose batteries are almost exhausted. As a general rule, such a procedure should not be adopted unless the storage battery is practically discharged, and then only when in the hands of an expert.

In driving an electric car the battery should be nursed as much as possible, on steep hills and rough roads. If the amperage rises abnormally when going up a steep hill it is better to tack from side to side than to go straight up the hill.

If the voltmeter shows a fall below 1.75 per cell, it does not necessarily indicate that the battery is exhausted or injured. The car should be stopped for a few minutes, when the normal voltage will again be shown. If this occurs often, however, the battery should be examined by an expert.

On receiving batteries unpack the cases carefully, opening them from the marked side. Clean off all excelsior or dirt that may have collected on the cells or trays.

Examine each connection carefully to see that none have been broken through rough handling in transit. If any are broken have a tinsmith solder the connec firmly, or when possible, have a lead-burned connection made.

Unscrew the stopper of each cell and see that the electrolyte covers the tops of the plates in each cell from one-half to one inch. If it does not more electrolyte should be added.

The electrolyte is made by mixing chemically pure sulphuric acid with distilled water until the specific gravity, when the liquid is cold, is about 1250.

The proportion of acid to water is about one part of the former to three and one-half parts of water.

Always add the acid to the water, not water to the acid. Heat is always evolved in adding acid to water and the electrolyte should always be allowed to thoroughly cool before adding it to cells.

Always use distilled or rain water, as other water is liable to contain iron or other salts injurious to plates.

Do not use distilled water from an ice plant, as it is almost sure to contain ammonia. The presence of the following substances in the electrolyte tends to destroy the plates: Chlorine, iron, copper, and the nitrates.

If any of the rubber cells have been broken or cracked in transit remove the cell from the tray at once, cutting its connection with the other cells, and order a new one in its place.

It may be determined whether a cell is leaking by adding more electrolyte, if it is found to be below the tops of the plates. After adding the electrolyte until the tops of the plates are covered, if in a short time the electrolyte is found to be lowering or below the plates again, the cell is imperfect.

Always have the batteries exposed to a free circulation of air when charging, removing the stoppers or vents to allow of the free escape of the gases.

Charge the battery at the normal rate specified until the electrolyte boils in the cells and the voltmeter indicates that each cell is giving 2.6 volts while the current is passing through the charging circuit. If the cells get hot reduce the charging rate one-half.

In order to obtain the best results the battery should never be allowed to be discharged to a voltage lower than 1.75 and if possible it should be stopped at 1.8 volts per cell.

Table No. 1 gives the weight, general dimensions and discharge rate for storage batteries of from 45 to 145 ampere-hour capacity.

TABLE NO. 1.

Weight in Pounds.	Outside Dimensions.			Discharge in Hours.			
	Width in Inches.	Length in Inches.	Height in Inches.	10 Amp.	15 Amp.	20 Amp	25 Amp.
9	5⅜	1⅜	10½	4½	....	....	....
12	5⅜	2	10½	7½	4¾	3½	....
15	5⅜	2⅝	10½	9¾	6½	4⅝	3⅝
19	5⅜	3¼	10½	12½	8¼	6	4⅝
22	5⅜	3⅞	10½	14¾	9¾	7¼	5⅝
26	5⅜	4½	10½	17½	11½	8½	6⅝
29	5⅜	5⅛	10½	19¾	13¼	9¾	7⅝
35	5⅜	6⅛	10½	25	16⅝	12½	10
24	6¼	3¼	10½	14¾	9¾	7¼	5⅝

When charging a storage battery the strength of the charging current should always be in proportion to the ampere-hour capacity of the battery.

The voltage of the charging circuit should be at least 20 per cent higher than the maximum voltage of the battery when fully charged.

When a storage battery is fully charged it should show 2.6 volts per cell, and the fact that the battery is fully charged will be indicated by an apparent boiling of the liquid and a free discharge of gases from the cells.

When charging storage batteries, great care should be taken to have the doors of the automobile body open, as while charging a great deal of hydrogen gas is thrown off, and no spark, lighted match or naked flame of any kind should be brought near the car during the process of charging.

When charging at high rates, great care should be taken not to heat the cells. If at any time the cells show a tendency to heat while charging, the charging current should be immediately reduced.

If at any time the batteries will not retain their charge after being fully charged, it is an indication that they are short-circuited. This is due to sediment settling so rapidly in the bottom of the cell that it touches the bottom of the plates in the cells. Nothing will tend to destroy a battery quicker than to try to operate it in the above condition, and whenever a battery shows an indication of not holding its charge, or falling far below its normal capacity, it should be inspected without loss of time.

Do not attempt to charge the battery at a high rate unless it is completely discharged, as the rate of charge that the battery will take is dependent upon the amount of energy already absorbed by the battery.

When charging a battery at a high rate, understand as near as possible the condition of the battery, as the high rate should only be used when the battery is completely discharged.

Always charge the battery promptly after using the car. Nothing will depreciate the battery capacity so much as to leave it standing discharged for some length of time, except using the batteries without the proper amount of solution in them. The solution should at all times extend above the top of the plates.

The charging circuit should always be supplied with a volt meter, ampere meter and rheostat. In this way the voltage of the battery can always be measured, or the amount of current it is desired to put into the batteries, can be measured by the ampere meter and the amount varied as desired by the use of the rheostat or resistance.

The cost of a charging outfit depends upon the size and capacity of the battery to be charged. One charging outfit is capable of charging one car several times a day or several cars a day.

A 60-ampere-hour storage battery charged from a

110-volt light circuit at a rate of 15 amperes, would require 4 hours to charge and would consume in that time from the light circuit, 110 volts, multiplied by 15 amperes, or 1,650 watts per hour, which, multiplied by 4 hours would be 6,600 watts, which, at 10 cents per thousand watts, would cost 66 cents. The cost per mile for operating an automobile would then simply be figured from the number of miles that a 60-ampere-hour storage battery would run the car.

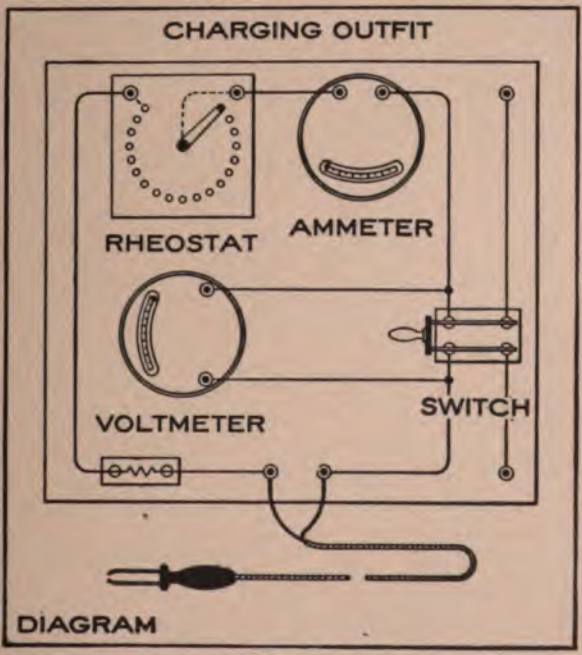


Fig. 73.

STORAGE BATTERY CHARGING SWITCH-BOARD.

A simple storage battery charging outfit is illustrated in Figure 73. Before inserting the charging plug into its receptacle on the car, always be sure that the controller lever is in the off position. After attaching the charging plug to the car, throw the rheostat lever over to its starting point, so that all the resistance is in the circuit, then close the jack-knife switch and regulate the charging current by means of the rheostat, until the proper charging rate given by the battery makers is reached. The charging of the batteries should always be done according to the instructions given by the makers of the car or battery.

The principal troubles to which a storage battery is subject are as follows:

One form of trouble that may occasionally happen to a battery is short circuiting. It is sometimes caused by the active material scaling off and falling between the plates, or by sediment in the bottom of the cell. Should a foreign substance fall between the plates when the cell is open, that is sufficient in many cases to cause trouble. Should trouble be suspected, it may be discovered by the marked difference in color of the plates or the specific gravity of the electrolyte, as compared with the other cells. No particular damage will be caused if the trouble is discovered and removed at once.

Corrosion of the plates may occur from the chemical action due to the electrolyte decomposition of dilute acid in the pores of the active material, or the presence of lead-dissolving acids or their salts in the electrolyte.

The corrosive action of liquids on metals immersed in them takes place with the greatest rapidity at the surface of the liquid, and storage battery plates which project above the surface of the electrolyte deteriorate at its surface before the submerged portions of the plate have greatly depreciated. The plates should always be completely covered with electrolyte, and the lugs which pass from the plates out to the terminals made of thick, rolled lead.

The causes of sulphating are over-discharge or too rapid discharge, either of the entire active material of the plates or only certain portions of it, and the injurious effects are those which arise from great increase in resistance and excessive expansion.

Local action will cause sulphating, as will also short-circuits between the positive and negative elements of the cell.

As the sulphate is white in color, its presence is indicated by the gradual lightening in color of the sulphated parts of the plates.

Internal discharge or local action is another source of trouble. The remedy is to use pure electrolyte and keep the plates well covered. Local action often results in filling the pores of the active material with impurities and sulphate, thereby reducing the capacity of the cell.

Loss of electrolyte by evaporation should be made up by proper addition of dilute acid, about 5 per cent of acid to 95 per cent of distilled water. If the electrolyte does not completely cover the plates a smaller portion of the active material is exposed, and the cell capacity proportionally decreased.

Fracture and buckling of the plates is due to excessive or unequal expansion. It indicates that the discharge has been carried too far, the rate too rapid, or the current distribution over the plate not uniform, and that certain portions of the plates were too far or too rapidly discharged.

Loss of the active material cannot be prevented if the active material is improperly formed or applied, and is of such composition that it disintegrates or loosens from the plate. Loss of the active material occurs, however, to a limited extent, due to too rapid expansion and contraction, which the plate cannot follow, or to the too rapid formation of gases when charging is done at a high rate, or the battery is overcharged.

Excessive or overdischarge tends to sulphate the exterior of the plates, which prevents the inner portion of the active material from participating in the discharge and causes the action to take place on the portion forming the outer layer, which results in overdischarge of the surface of the plate and the formation of a non-reducible sulphate.

This occurs frequently in a battery, one or more cells showing a lower voltage than the rest, and at times their polarity may even be reversed. This diminished voltage is due to surface sulphating of the active material in the plates, which must be removed.

CHAPTER XVIII.

CARBURETERS.

Carbureters for gasoline motors are of three types: surface carbureters, in which the air supply is mixed directly with gasoline vapor to form an explosive mixture—spray or jet float-feed carbureters, which, by means of a float, maintain a constant level in the gasoline receptacle and mixing valves, in which the gasoline outlet is opened by means of an air valve.

The surface carbueter is at the present time almost obsolete, being used only on one or two motor-bicycles of European make. The rapid evaporation of the vapor in the surface carbureter, due to the suction of the motor-piston, causes the gasoline after a short time to become thick and syrupy, and if some external source of heat is not supplied to assist in the evaporation it will cease altogether. While the surface carbureter is the most economical of the three forms, it is very irregular and erratic in its action and requires constant manipulation of the air and gasoline vapor cocks to insure at all times an explosive mixture of uniform quality. The float-feed form of carbureter consists of two principal parts: a gasoline receptacle which contains a hollow metal or a cork float, suitably arranged to control the supply of gasoline from the tank or reservoir, and a tube or pipe in which is located a jet or nozzle in communication with the gasoline receptacle—this tube or pipe is called the mixing chamber. The gasoline level is maintained about one-sixteenth of an inch below the opening in the jet in the mixing chamber. The inductive action of the motor-piston creates a partial vacuum in the pipe leading from the mixing chamber of the carbureter to the motor, thereby causing the gasoline to flow from the jet and mixing with the air supply, to be drawn into the cylinder of the motor in the form of an explosive mixture.

The carbureter shown in the accompanying illustration, Figure 74, is of the jet form of float-feed type.

The chamber A of the carbureter contains the float B, through the center of which passes the stem of the needle-valve C, which keeps the pipe D leading to the gasoline tank normally closed. When the level of the gasoline in the chamber A falls, the float B, through the links E, small levers F and grooved collar G, raises the stem of the needle-valve C, thus permitting more gasoline to enter the chamber A, until the normal level is again restored.

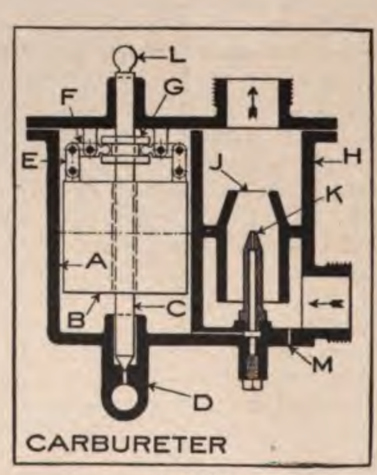


Fig. 74.

JET TYPE OF FLOAT-FEED CARBURETER.

The mixing-chamber H nas an inner tube J, which surrounds the jet or nozzle K. During the admission stroke of the motor-piston, air is drawn into and through the mixing-chamber H, in the direction of the arrows, a small stream of gasoline is in consequence drawn up by suction from the opening in the jet or nozzle K, mixing with the air in the chamber H. The upper end of the stem of the needle-valve C is provided with a small knob L, by which the carbureter may be flushed for the purpose of starting the motor. Any surplus gasoline is carried off by means of the vent M.

The spray form of float-feed carbureter shown in Figure 75, has the float B and needle-valve stem C in one piece. When the gasoline level in the chamber A is lowered, the needle-valve stem C falls with the float B and allows more gasoline to enter the chamber A, through the opening in the connection at D. The screw E with thumb-piece F and lock-nut G is for the purpose of regulating the volume of the spray at the nozzle K, by means of the cone-shaped point H of the screw E. The nozzle K is surrounded by a tube J, through which the air is drawn by the inductive action of the motor-piston. The carbureter may be flushed by depressing the float with the small plunger M, which is kept normally out of contact with the float by the spring L.

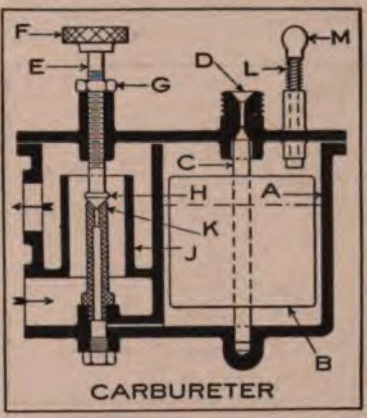


Fig. 75.

SPRAY TYPE OF FLOAT FEED CARBURETER.

Since the adoption of liquid fuels for explosive motors, numerous forms of carbureters have been designed, with a view to eliminate the complications of the float-feed type. The most practical form of such devices, known as mixing valves, are very suitable for marine or automobile motors, where the speed is not constantly being changed, and are specially adapted for motors that run at a uniform speed. Figure 76 illustrates one form of mixing valve. It consists of globular chamber A, within which is a valve B, controlled by a spring C carried by the seat D on the valve-stem guide E, which forms a part or portion of the threaded cover F. The gasoline from the supply tank is fed through a suitable pipe screwed into the threaded connection at G, to the opening in the seat of the valve B. The rate of feed of the gasoline is regulated by means of the needle-valve H, with knurled thumb-nut J and lock-spring K. The suction of the motor-piston draws the valve B from its seat and at the same time uncovers the opening in the valve seat leading from the gasoline supply pipe at G and allows of the flow of a small quantity of gasoline.

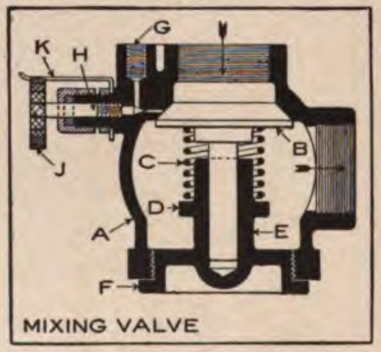


Fig. 76.

MIXING VALVE WITH GASOLINE INLET IN VALVE SEAT.

The gasoline mixes with the air drawn through the valve opening and the friction of passing around the narrow space between the valve and its seat insures a uniform mixture of gasoline and air.

Another form of mixing valve is shown in Figure 77, in which the gasoline supply is controlled by the cone-point on the stem A of the valve B. The cone-point of the valve-stem A entirely closes the opening leading from the supply pipe at G, but keeps the valve B slightly off its seat as shown.

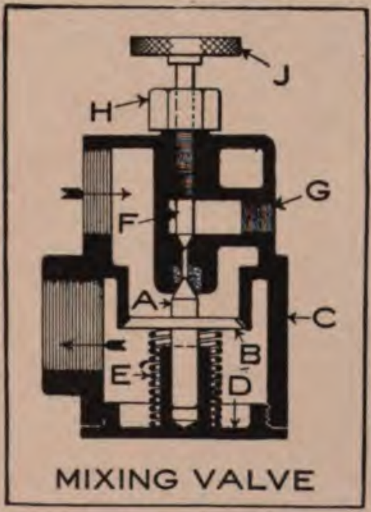


Fig. 77.

MIXING VALVE WITH GASOLINE INLET AT UPPER END OF THE VALVE STEM.

The valve B is held in position by means of the spring E, located around the guide of the valve-stem, which rms a part of the cover D of the valve chamber C.

mount of gasoline fed to the motor. is regulated rew F, with thumb-nut J and lock-nut H.

The air is drawn through the carbureters or mixing valves in the direction indicated by the arrows.

There are several things which may prevent a proper explosive charge from reaching the combustion chamber of a motor. Some of the principal causes may be enumerated as follows:

A leak or crack in the pipe between the carbureter and the admission-valve chamber—Partially or entirely close the air inlet to the carbureter, then try and obtain an explosion from the motor. If it should start, the trouble is probably located and the admission-pipe should be closely inspected for leaks or cracks.

Not enough gasoline—Proceed as above and if the motor starts, the nozzle in the mixing chamber of the carbureter should be removed and the opening cleaned by passing a wire through it, the needle-valve opening should be treated in a like manner.

Too much gasoline—Shut off the gasoline supply at the tank and crank the motor. If the motor starts, the trouble is located and the gasoline supply should be regulated, by throttling at the supply tank, or if possible by replacing the nozzle with one having a smaller opening.

Dirt in the gasoline—When filling the gasoline tank always use a strainer-funnel: one that is fitted with a wire-gauze screen of very fine mesh. In the absence of a strainer-funnel, three or four layers of fine linen may be fitted inside an ordinary funnel. A piece of chamois skin also makes an excellent filtering medium. Never use the same funnel for both gasoline and water.

Leak in the float—This may be from the fact that one of the soldered joints has opened, or minute perforations occurred, by corrosion due to the presence of foreign substances in the gasoline. In either case the float will partially or wholly fill with gasoline and sink to the bottom of the float chamber, thus opening the needle-valve and flooding the carbureter. The only remedy for this is a new float.

Poor quality of gasoline—This is [illegible]ally indicated by a smoky exhaust with a disagree[illegible]. the motor will misfire occasionally and not develop its full power. Gasoline should always be tested with a densimeter when its quality is in doubt and if it does not show at least 76 degrees it should be rejected. In the absence of a testing outfit, a handy and fairly reliable method of testing the fuel is to pour a little of the doubtful gasoline on the palm of the hand. If the gasoline evaporates rapidly and leaves the hand dry and clean, it may be safely used, but if it evaporates slowly and leaves a greasy deposit on the hand, its use should be avoided.

Water in the carbureter—All gasoline contains a slight percentage of water, which, being heavier than the more volatile liquid, settles to the bottom of the gasoline tank and eventually finds its way to the carbureter. This generally happens after a car has been standing for some days and not in use. The gasoline supply should be shut off at the tank and the carbureter emptied by opening the pet cock usually provided for this purpose at the bottom of the float chamber.

Stale gasoline—The gasoline in the float chamber of the carbureter will lose its strength if the car has been standing for some time not in use—Shut off the gasoline supply at the tank and then empty the float chamber by means of the pet-cock which is usually provided for this purpose. After the float chamber is emptied, close the pet-cock and turn on the gasoline supply at the tank.

Cold weather—Saturate a piece of waste with some fresh gasoline and insert it in the air-inlet of the carbureter—In extremely cold weather it may be necessary to warm the carbureter and admission-pipe by pouring boiling water over them, but on any account do not start a bonfire under the carbureter.

Water in the gasoline—Pour a small quantity of the gasoline on a smooth, unpainted metal surface, the water will separate from the gasoline and collect in small globules, unless the water has been purposely combined with the gasoline by the use of some chemical, at the hands of an unscrupulous dealer—If this is suspected, a small quantity of the gasoline when ignited will burn slowly with a yellowish flame.

Starting crank not turned fast enough—Always remember that a few quick turns of the crank will be more likely to start the motor than ten minutes of slow pumping.

CHAPTER XIX.

COMPRESSION AND COMBUSTION CHAMBERS.

ADVANTAGES OF COMPRESSION.

The compression pressure of an explosive motor should be as high as is possible, without danger of reaching the degree of compression at which premature or self-ignition of the charge would occur.

A high degree of compression is of great advantage, but it is not generally known that during compression there is a loss of heat from the gases to the walls of the motor cylinder. If the time or period of contact of the gases with the cylinder walls were less, the heat losses would be smaller. Hence the mean temperature of the gases during the compression stroke of the motor increases with the motor speed and consequently the gases ignite far more readily when the motor is running at a high rate of speed, than when running slowly or being operated by hand.

The higher the compression, therefore, the quicker the ignition and consequent expansion of the gases take place, thereby causing them to attain a greater initial pressure, on account of the lesser heat losses through the cylinder walls. As it takes a certain length of time to dissipate or radiate a certain amount of heat, it follows as a natural sequence that the shorter the time occupied by the burning gases to attain their highest pressure, the smaller the heat losses by dissipation or radiation. The principal gain by the use of high compression is secured from the fact that the motor may be run at a greater number of revolutions per minute, thus having more working strokes or power impulses and hence greater power, than if using a lower degree of compression and consequently slower speed.

The compression in atmospheres of a motor may be readily found by dividing the cubic contents of the piston displacement by the cubic contents of the combustion chamber in cubic inches, and then adding one to the result.

To ascertain the compression in atmospheres of a motor, when the cubic contents of the combustion chamber are known: Let S be the stroke of the piston in inches and A the area of the cylinder in square inches. If C be the contents of the combustion chamber in cubic inches and N the required compression in atmospheres, then

$$N = \left(\frac{S \times A}{C}\right) + 1$$

Example: Find the compression in atmospheres of a motor of 4-inch bore and 6-inch stroke, whose combustion chamber has a capacity of 18 cubic inches.

Answer: Six multiplied by 12.56 equals 75.36, which divided by 18 gives 4.19, and 4.19 plus 1 equals 5.19, or the compression in atmospheres required.

If it is desired to ascertain the compression in atmospheres of a motor, the combustion chamber of which is of such shape that its dimensions cannot be accurately calculated, its cubic contents may be found by filling the combustion chamber with water, and after removing the water, ascertaining its weight in ounces, and then multiplying the result by 1.72. This gives the capacity of the combustion chamber in cubic inches. The compression of the motor can then be readily calculated from the formula given herewith.

To discover if there are any leaks in the compression of a gasoline motor, a small pressure gauge reading up to 75 pounds should be fitted into the spark plug opening in the combustion chamber by means of a reducing [illegible]ing. When turning the starting crank of the [illegible] slowly the gauge should indicate at least 60 [illegible] square inch if the compression is in good [illegible]

To test for leaks, fill a small oil can with [illegible] and squirt round every joint [illegible] there may be [illegible] sible chance for leakage. Get an assistant to turn the crank and watch for bubbles at the joints.

If the joints are all tight, next examine the condition of the admission and exhaust-valves and if either of them needs regrinding, it should be done, first with fine emery powder and oil, then finished with tripoli and water.

When the valves have been ground to a perfect fit, if the compression still leaks, the piston rings should be examined, as the trouble will be found to be with them.

COMBUSTION CHAMBERS.

That part of an explosive motor in which the gases are compressed and then fired, usually by an electric spark, is known as the combustion chamber. The interior of the combustion chamber should be as smooth as possible and kept free from soot or hard carbon deposits such as are induced by excessive lubrication or the use of too rich an explosive mixture.

It will be found to be no small task in designing an explosive motor with the usual form of valve construction and operation, to keep the combustion chamber down to the required dimensions and at the same time have it free from bends or contracted passages between the combustion space and the valve chamber.

Many attempts have been made to obviate this difficulty by making the combustion chamber simply a straight extension or continuation of the cylinder. In this manner both the admission and exhaust-valves can be placed in the cylinder itself and an ideal combustion space secured. This plan has, however, certain disadvantages, from the fact that it not only lengthens the motor, but requires a more complicated form of valve operating mechanism than if the valve chamber were at the side of the cylinder as is usual.

If it is desired to ascertain the cubic contents or dimensions of the combustion chamber of an existing motor, they may be found by filling the combustion space with water, then obtaining the weight of the water in ounces, which multiplied by 1.72 will give the capacity of the chamber in cubic inches. If a motor is to be designed with a given bore and stroke, the first thing to do is to decide on the amount of clearance or combustion space at the end of the cylinder for the gases to occupy after compression.

If the combustion space could be made as a continuation or extension of the cylinder bore, it would be an easy matter to determine the required clearance, as it would simply be some fraction of the total piston stroke.

But as the general design of a combustion chamber deviates widely from a plain section or length of a cylinder as above described, being in some cases flat oval, elliptical, semi-spherical and even rectangular in cross section, some other method must be used to calculate the required clearance.

To do this correctly the contents of the combustion chamber in cubic inches must first be ascertained, and then apportioned between the valve chamber or chambers and the clearance proper which lies directly behind the piston head.

To find the cubic contents of a combustion chamber when the degree of compression in atmospheres is known: Let S be the stroke of the piston in inches and A the area of the cylinder in square inches. If N be the number of atmospheres compression and C the required contents of the combustion chamber in cubic inches, then

$$C = \frac{S \times A}{(N - 1)}$$

Example: Find the cubic contents of the combustion chamber for a motor of 4-inch bore and 5-inch stroke with 4 atmospheres compression.

Answer: Five multiplied by 12.56 equals 62.83, which divided by 3 gives 20.94 as the number of cubic inches required.

CHAPTER XX.

ELECTRIC AUTOMOBILE MOTORS.

A well designed electric motor for use in connection with a storage battery for automobile propulsion must be capable of withstanding an overload of over 100 per cent for at least thirty minutes at a time, or for even a longer period, without unduly overheating. The motors used on electric automobiles are usually series-wound, as this type of winding has been found to give the most satisfactory results in general use.

There are three types of electric motors in general use, these are:

Shunt-wound motors, in which the field-magnets are wound with a great many turns of very small wire, the ends of which are directly connected to the terminals of the commutator brushes.

Series-wound motors, which have the field-magnets wound with a few turns of very large wire. One end of this wire is connected to one commutator brush terminal. The other end of the wire on the field-coils and the other brush terminal being connected with a battery or other source of current.

Compound-wound motors are a combination of the above motors, having the field-magnets double-wound, that is with both shunt and series-windings.

The armature of an electric motor is built up of a number of disks of sheet iron, which are separated from each other by a suitable coating of varnish or by the use of thin sheets of paper between the disks, this is to prevent what are [illegible] as eddy currents, which are a source of const[illegible] if not eliminated.

The functio[illegible]mmutator of an electric motor is to receive th[illegible]om the battery or other source of power, by [illegible]e brushes, and transmit it to the windings or coils upon the periphery of the armature.

The essential features of an electric motor are as follows:

The brushes, which are located upon and around the periphery of the commutator and serve to transmit the current to the commutator from the outside source or supply.

The commutator or current distributor and laminated wrought iron armature.

The field-magnets and pole-pieces, the latter are usually an extension of the magnet core.

The magnet frame, usually of cast steel.

Figure 78 shows a form of series-wound electric motor of the style most commonly used for automobile work. The motor is of the four-pole type, having its field-coils arranged at equi-distant points around the periphery or circumference of the armature. The armature shaft is carried by ball-bearings, with suitable screw and clamp adjustment as shown. The armature is of the slot-wound type and has a commutator with self-adjusting carbon brushes. The left-hand extension of the armature shaft is fitted with a key and washer for the driving gear or sprocket, while the right-hand end has a pulley or brake wheel to use for stopping the car under ordinary conditions of travel. The magnet frame is of cast steel and the magnet cores and armature disks of laminated wrought iron. The field-coils are machine-wound and the armature coils form-wound, while both are thoroughly taped and waterproofed. The commutator generally has the same number of sections as the armature has slots and is usually of large diameter and wide contact face.

Electric motor troubles may be classed as follows: Open-circuits, improper connections and short-circuits.

An open-circuit may be found at any one of the following places:

Battery terminals. These may be badly corroded or worked loose, so as to form a poor or improper electrical contact.

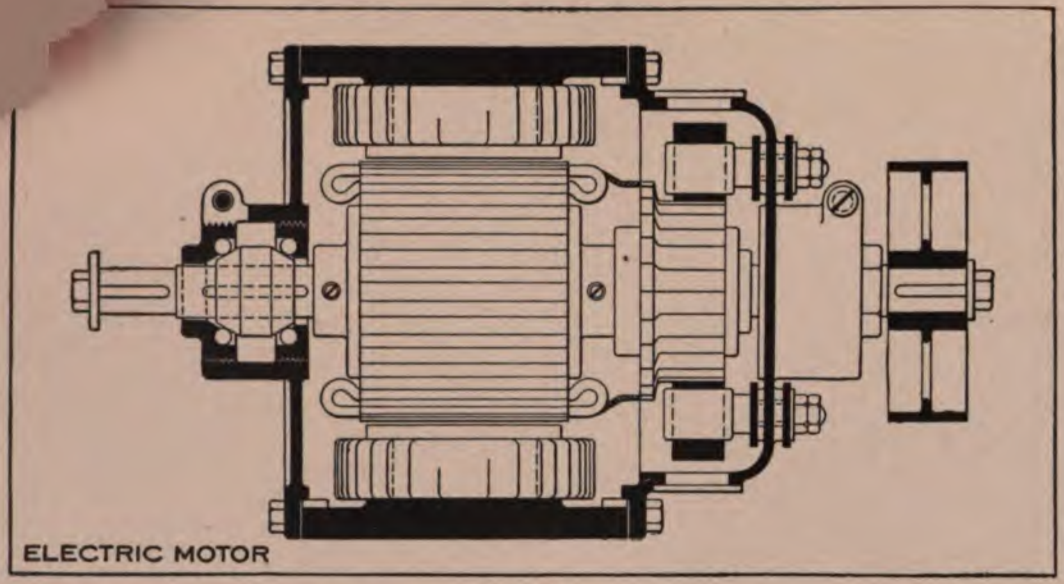


Fig. 78.

SERIES WOUND, ENCASED, ELECTRIC AUTOMOBILE MOTOR.

Controller. A connection may have worked loose, or the spring contact-fingers are not making good contacts.

The removable plug may be out or not making a proper contact.

Brushes. One of the carbon brushes of the motor may have fallen out, or the brush springs may be too weak to insure a good contact.

The reversing switch may be halfway over, thus leaving the batteries and motor on an open circuit.

All points of contact, such as terminals or binding-posts, brush-holders, switches and controller spring contact-fingers, should be bright and clean so as to give a perfect metal-to-metal contact.

The fact that the car will not start and the ammeter shows no current indication is generally a sign of improper battery connections.

When the different trays of the battery are not properly connected together, short-circuits will occur between these sections and run down or exhaust the batteries in a very short time. All battery terminals should be plainly marked so that it is impossible to make wrong connections. If the trouble above stated occurs the battery trays must be wrongly connected amongst themselves.

If the ammeter indicates a large current and the motor refuses to turn, the trouble is what is known as a short-circuit, or a path for the current outside of the motor.

Lift one of the commutator brushes and if the amperage shown by the ammeter drops, or perhaps disappears altogether, one of the field-coils is short-circuited or there is a broken wire touching some part of the metal of the car or an exposed portion of another wire.

The speed and consequently the power of an electric motor may be varied in three ways, as follows:

First, by introducing variable resistance in the motor and battery circuit.

Second, by varying the voltage of the batteries by different combination of the battery trays.

Thirdly, by connecting the field-coils of the motor, all in series, in series-parallel and all in parallel. Various other combinations of the above named methods may also be had.

ELECTRIC LIGHT OUTFITS.

Although gas and oil engines for electric lighting purposes are of special design, the lights may sometimes flicker. Flickering in the incandescent lights may be located by close inspection of the engine and dynamo, and may be due either to the flywheels, the governor or the belt. To locate this defect and remedy it, notice the lamps carefully. If the variations in the light are due to lack of weight in the rim of the flywheel, these variations will be seen to coincide with the revolutions of the engine. Again, if the variation in the lights is only periodical, then this defect should be remedied by adjustment of the governor. Examine the governing mechanism of the engine. If the variation is caused by the governor acting too slowly, then adjust the governor so as to cause more rapid action upon the controlling mechanism.

The cause of the trouble may not be, as already suggested, in the flywheel or in the adjustment of the governor,but in the belt, which is frequently the sole cause of flickering in the lights. The engine and dynamo pulleys over which the belt runs should be exactly in line with each other. The belt should be made endless, or if jointed the joints should be very carefully made. A thick, uneven joint in the belt will cause a flicker in the lights each time it passes over the dynamo pulley.

Figure 79 shows a two-cycle gasoline engine directly connected to a dynamo, both engine and dynamo being mounted on a cast iron base.

To secure a steady light with gas or oil engines, the practice has been to place a flywheel upon the dynamo shaft, as the speed of some engines sometimes varies as much as 5 per cent. The constructional details of some gas engines used for this purpose have been so considerably improved that the dynamo flywheel is not considered necessary.

This uniform speed has been largely secured by increasing the diameter and weight of the flywheels, together with an improved method of direct balancing, the balance being fitted to the crank, instead of to the rim of the flywheel, which is usually the case with ordinary engines. Very sensitive governing gear, however, is necessary.

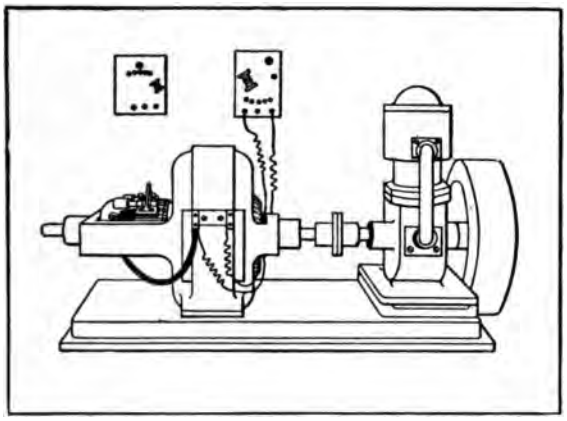


Fig. 79.

ELECTRIC LIGHT OUTFIT, SHOWING TWO-CYCLE ENGINE DIRECT-CONNECTED TO DYNAMO.

CHAPTER XXI.

FRICTION DRIVES.

Since the inception of power-driven machinery, one of the principal requirements has been some form of speed-changing device to suit the varying conditions of the work. Devices for this purpose are of such innumerable forms and types that it would not be within the scope of this work to discuss them.

The oldest form of speed-changing device in use consists of two sets of pulleys of different diameters on parallel shafts, driven by an endless belt. Change of speed is affected by shifting the belt from one set of pulleys to another. Another method is by two sets of gears, arranged so that the required pair of gears can be either slid into mesh, or be brought together by means of an eccentric. Taper pulleys in the from of truncated cones with their unlike ends adjacent on parallel shafts and belt driven, form a third means of variable speed transmission, the change being effected by sliding the belt along the surface of the cones while they are in motion.

In the disk and roller transmission, a roller engages the flat surface of a disk, and transmits power by pressure being brought to bear upon the contact surfaces. The speed is increased or decreased by sliding the roller along the face of the disk between the center and the edge. By moving the roller to the right or left of the center of the disk, the direction of motion of the roller or the disk may be changed at will. If the disk be the driver the direction of rotation of the roller will be changed, and if the roller is driving the direction of the rotation of the disk will be changed, when the roller [illegible] from one side of the center of the disk to the [illegible]

[illegible] forms mentioned, the sets of pulleys [illegible] capable of changes of speed in fixed ratios as 1-2-3 or 1-3-9, etc., while the third, the twin taper pulley or cone form, will give a gradual variation of speed, with the normal driving speed at a halfway point in their length if they are of similar dimensions throughout. The disk and roller form of speed-change transmission is not only capable of giving a gradual increase or decrease of speed, but, as before stated, by sliding the roller from one side of the center of the disk to the other, a change in the direction of rotation of either roller or disk may be effected.

But the disk and roller form of variable speed transmission has an objection in the fact that the portion of the face of the disk which is in contact with the roller does not travel at a uniform rate of speed throughout the length of the roller contact. Suppose the roller were made in three separate sections, with only line contacts or knife edges, one inch apart, and that the radius of travel of the center section of the roller from the center of the disk was four inches, and for the inner and outer sections, 3 and 5 inches respectively. The travel of the center section of the roller on the surface of the disk for one revolution would be 25.13 inches, for the outer section 31.42 inches, and for the inner section 18.85 inches. This plainly shows that slippage must take place during the transmission of power by means of the disk and roller method.

In spite of this fact and on account of its simplicity of construction the disk and roller form of variable speed transmission is in use for a great many different purposes in the mechanical arts. Examples are small drill presses, grinding machines and countershafts. In automobile use it forms an ideal method of transmission with variable speed and reverse or change of direction, without gears or belts.

While there are a great many combinations and adaptations of the disk and roller form of variable speed power transmission in use, they are all based on the three elementary forms of construction shown in the accompanying drawings.

The upper view in Figure 80 shows one form of disk and roller transmission, in which the disk forms an integral part of the motor flywheel, and the power is transmitted to the driving wheels of the vehicle by suitable means from the roller shaft. As the power to be transmitted by the device is at all times proportional to the velocity, in feet per minute, of the path of travel of the roller on the disk, and to the pressure at the contact between the disk and roller, it follows that the nearer the center of the disk the roller travels, the less its velocity, and the greater the pressure required between the disk and roller to transmit the same power. In this type the disk velocity is uniform and the roller speed variable.

The center view is another form of disk and roller transmission, in which the roller is slidably located upon the motor shaft, and the power transmitted to the driving wheels of the vehicle, through the medium of a countershaft carrying the disk. With this arrangement, as the roller speed is constant, the speed of rotation of the disk will vary, as the roller is moved from the center to the periphery of the disk. The same pressure is required to transmit the same power when the roller is at the periphery of the disk, and the disk shaft at its slowest speed, as when the roller is near the center of the disk, and the disk shaft at its highest speed.

Another form of disk and roller transmission, in which two rollers and disks are employed, is shown in the lower view. One roller and disk run loose. By this method twice the power can be transmitted as in the case of the constructions previously illustrated. Double the pressure must, of course, be put upon the loose disk to effect this increase of power. When both rollers are at the periphery of the driving disk on the motor flywheel, the pressure upon both rollers is alike, as the idle roller transmits its portion of the power through the idler [illegible] to the sliding roller, thus giving twice the [illegible] the single roller device. When the sliding [illegible] toward the center of the disks, the press[illegible] disk is increased upon the sliding [illegible] decreased upon the idle roller, [illegible] tractive effort than if the idle

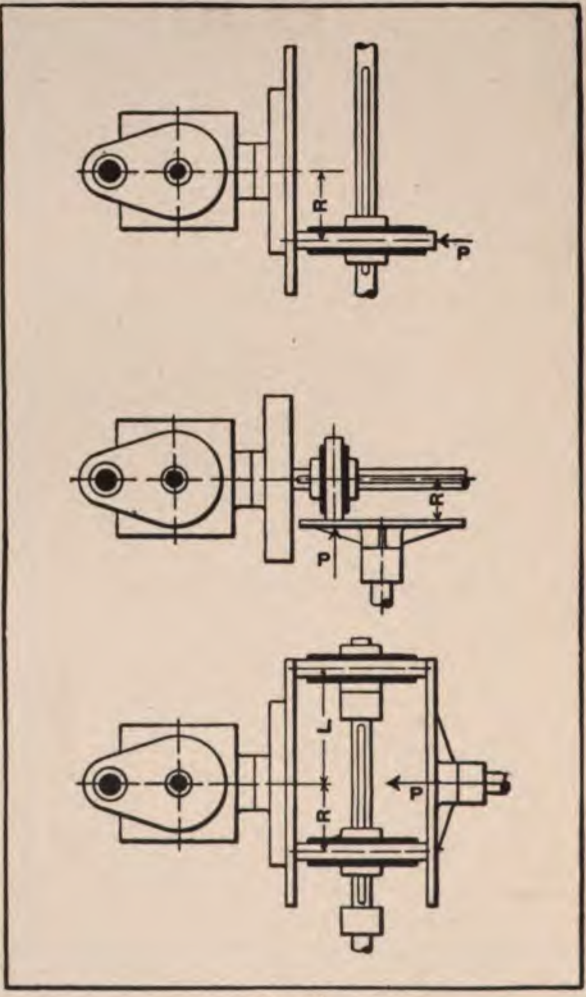


Fig. 80.

THREE TYPES OF AUTOMOBILE FRICTION DRIVES.

roller were not used. While slightly more complicated, the advantage of this construction over the other forms is obvious. While the pressure upon the idler disk is doubled, the pressure upon the contact surface of the driving roller is the same as if only one roller were used and but half the power transmitted.

The following formulas deduced from the results of tests give the power which can be transmitted by the constructions shown in Figure 80.

Let P be the pressure in pounds between the contact surfaces of the disk and roller, F the width of the face of the roller, C the coefficient of adhesion or tractive effort between the contact surfaces, N the speed in revolutions per minute, R and L the radii as shown in the drawings, and H.P the horsepower transmitted by the disk and roller. Then

$$H.P = \frac{P \times F \times C \times N \times R}{21{,}000} \text{ (Nos. 1 and 2)}$$

$$H.P = \frac{P \times F \times C \times N \times R \times L}{63{,}000 \times (R+L)} \text{ (No. 3)}$$

The values of C for different materials are given as follows:

0.15	Cast Iron and Cast Iron.
0.18	Cast Iron and Copper.
0.25	Cast Iron and Rawhide.
0.27	Copper and Rawhide.
0.30	Rawhide and Rawhide.

Example: What will be the maximum and minimum horsepower transmitted by a disk and roller of the form illustrated in the upper view in Figure 80 with copper-faced disk and cast iron roller of 1 inch face? The contact circles on the disk are 3 and 7½ inches respectively, and the motor speed is 900 revolutions per minute, with 100 pounds pressure at the contact surfaces.

Answer: As the coefficient of traction for cast iron and copper is 0.18, then the minimum will be: $100 \times 1 \times 0.18 \times 900 \times 3$, or 48,600, divided by 21,000, which gives 2.31 horsepower. The maximum will be 100×1 ×0.18×900×7.5, which equals 121,500, divided by 21,000, giving 5.78 horsepower.

Example: Under the same conditions with a roller 6 inches in diameter, what horsepower will the form of transmission illustrated in the center view in Figure 000 transmit for minimum and maximum disk speeds?

Answer: As the speed of the roller is constant and the disk speed varies as the roller is moved in or out from the center, the power transmitted will be constant at any portion of the surface of the disk, and will be the same as the minimum power for the form illustrated in the above example, that is, 2.31 horsepower. As the leverage is increased as the roller moves out, the speed of the disk is correspondingly decreased, or vice versa.

CHAPTER XXII.

GASOLINE.

A number of fires have been caused by leaky gasoline pipes on automobiles and many persons would like to know chemicals which can be used to put out such fires. Water is an exceedingly dangerous proposition to use and it is not always possible to get at the fire to smother it with wet rags or waste.

In case of fire due to gasoline, use fine earth, flour or sand on top of the burning liquid. Never use water, it will only serve to float the gasoline and consequently spread the flame.

A dry powder can be used for this purpose which will extinguish the fire in a few seconds. It is made as follows: Common salt, 15 parts—sal-ammoniac, 15 parts—bicarbonate of soda, 20 parts. The ingredients should be thoroughly mixed together and passed through a fine mesh sieve to secure a homogeneous mixture.

If by any chance a tank of gasoline takes fire at a small outlet or leak, run to the tank and not away from it, and either blow or pat the flame out. Never put water on burning gasoline or oil, the gasoline or oil will float on top of the water and the flames spread much more rapidly. Throw fine earth, sand or flour on top of the burning liquid. Flour is best. The best extinguisher for a fire of this kind in a room that may be closed, is ammonia. Several gallons of ammonia, thrown in the room with such force as to break the bottles which contain it, will soon smother the strongest fire if the room be kept closed.

Benzine, Gasoline, Kerosene and the kindred hydrocarbons are products of crude petroleum.

They are separated from the crude oil by a process of distillation. The process is very similar to that of generating steam from water.

Crude petroleum subjected to heat will give off in the form of vapor such products as Benzine, Gasoline and Kerosene, etc. The degrees of heat at which these products are separated are comparatively low. Various degrees of heat will separate the distinct products. As a means of illustration, it may be said that the crude oil when raised to certain temperatures gives off vapors which when cooled liquefy into what are known as Benzine, Gasoline and Kerosene.

A lighted match placed at the opening of a new 2-gallon can of gasoline merely caused a small flame an inch long, which could be extinguished with the point of a finger.

Gasoline was poured into an open vessel and a lighted cigarette dropped into it. Result: It was at once extinguished.

A lighted cigarette was smoked vigorously from within two feet above to a quarter of an inch of the gasoline—also all around and underneath the vessel, but no ignition occurred.

A small quantity of gasoline was poured on a cigarette while smoking—still no ignition occurred.

A can was then made hot, and the gasoline poured into it, so that it would vaporize more quickly—a lighted cigarette was then smoked into it, as in the third case, but failed to cause ignition.

There are two entirely different kinds of explosion, which would undoubtedly both be referred to as gasoline explosions. The real gasoline explosion is the kind taking place in the cyclinder of a gasoline motor, in which heat and pressure are suddenly produced by the combustion of gasoline vapor in air. The other kind of explosion referred to may be explained as follows:

If a tank of gasoline be placed on a woodpile and the latter set on fire, the heat would raise a pressure in the tank, which would rapidly increase and the tank would finally explode from the pressure. The gasoline would then be thrown in all directions, and, owing to its superheated condition, the greater part of it at least would instantly vaporize, mix with the air of the atmosphere and be ignited by the flame which caused the explosion.

The following table, No. 2, gives the thermo-dynamic properties of gasoline and air and may be of interest, in view of the fact that information on this subject is sparse and most of that only theoretical or empirical deductions.

This table gives the explosive force in pounds per square inch of mixtures of gasoline vapor and air, varying from 1 to 13 down to 1 to 4, also the lapse of time between the point of ignition and the highest pressure in pounds per square inch attained by the expanding charge of mixture. The tests from which the results given were obtained, were made with a charge of mixture at atmospheric pressure, so as to more accurately note the results, as the mixture takes much longer after ignition to attain its highest pressure, and is slower also in expanding.

It may be well to remember that there are no more heat-units, and consequently no more foot-pounds of work in a mixture of gasoline and air, under 5 atmosphere compression, than under 1 atmosphere compression.

Flanged or ribbed air-cooled motors will approach the figures given in the table for the initial explosive force for the varying compressions, very closely, while thermal-syphon water-cooled motors will come within about 20 per cent of these results, and pump and radiating coil cooled motors will come within about 30 per cent. While it appears at the first glance that the proper thing to do to get the greatest efficiency from a motor would be to let it run as hot as possible, experience has shown that the repair bill of a hot motor will more than offset its efficiency over the cooler water-jacketed motor, with pump and radiating coils. The last two columns in the table give the temperature of the burning gases, the first of the two columns the actual temperature with the accompanying mixture of gasoline and air, and the second the theoretical temperatures, or temperature to which the burnin [illegible] ture should attain, if there were no heat [illegible]se[illegible]

TABLE NO. 2.—THERMO-DYNAMIC PROPERTIES OF GASOLINE AND AIR.

Gasoline, Vapor and Air.	Time in Seconds between Ignition and Highest Pressure.*	Explosive Force in Pounds per Sq. In.			Temperature of Combustion in Degrees Fahrenheit.*	
		Compression in Atmospheres.				
		3	4	5	Actual.	Theoretical.
1 to 13	0.28	156	208	260	1875	3542
1 to 11	0.18	183	244	305	2196	4010
1 to 9	0.13	234	312	390	2803	4806
1 to 7	0.07	261	348	435	3119	6001
1 to 5	0.05	270	360	450	3226	6854
1 to 4	0.07	240	320	400	2965	5517

*At atmospheric pressure.

CHAPTER XXIII.

GAS AND OIL ENGINES.

CYCLES OF GAS AND OIL ENGINES.

The four-cycle engine, having only one working stroke or impulse during each two revolutions of the crank shaft, consequently requires larger and heavier flywheels than a two-cycle engine in order to maintain a practically uniform speed and also to transmit the power during the idle strokes of the engine.

The four-cycle engine has, however, many advantages over the two-cycle engine. The working stroke or impulse is more readily controlled, and during the inlet and exhaust strokes a longer time is allowed for the cooling of the valves and the more thorough expulsion of the exhaust products from the cylinder than is possible with a two-cycle engine.

In the two-cycle type of engine the charge must be independently compressed before entering the cyclinder of the engine, in some two-cycle engines this is accomplished in a separate cylinder, but usually in the crank case of the engine.

A greater quantity of lubricating oil and more cooling is required with a two-cycle than a four-cycle engine on account of the greater amount of heat generated in the same length of time.

Six-cycle or scavenging engines have been largely used, in which after the termination of the exhaust stroke, a charge of air is drawn into the cylinder and the products of combustion thus entirely expelled.

As such engines have only one working stroke or impulse to every three revolutions of the crank shaft, the cylinder and flywheel dimensions require to be greatly in excess of those of engines of the four-cycle type, necessitating greater floor space, increased weight, excessive wear and tear and greater complication of the valve-operating mechanism.

EFFICIENCY OF GAS OR OIL ENGINES.

The mechanical efficiency of a gas or oil engine depends on its design, workmanship and proper lubrication, and also on:

The proper mixture of air and fuel.
The correct degree of compression.
The correct point of ignition.
The duration and completeness of combustion.
The rapidity and amount of expansion.
Efficient governing and free exhaust.

If any doubts exist as to the engine giving out its proper power, a brake test should be made.

To ascertain the mechanical efficiency of a gas or oil engine, both indicator and brake horsepower tests should be made, then if I.H.P. be the indicated horsepower and B.H.P. the actual or brake horsepower of the engine and M.E. be its mechanical efficiency, then

$$\text{M.E} = \frac{\text{B.H.P.}}{\text{I.H.P.}}$$

If the brake horsepower of an engine be 7.5 and the indicated horsepower be 10, then the mechanical efficiency will be

$$\text{M.E} = \frac{7.5}{10}$$

which equals 75 per cent.

In text-books the efficiency of an engine is usually considered as the relation between the heat-units consumed by the engine and the work or energy in foot-pounds given out by it. If the heat-units (which are measured by the quantity of fuel supplied to the engine) be large compared to the work or energy given out by the engine, its efficiency is small.

The ratio of the heat utilized by the engine, as shown by the power developed, as compared with the total heat contained in the fuel absorbed by the engine, is known as the thermal efficiency. This can be obtained by the following formula:

Let F=consumption of fuel in pounds per brake horsepower per hour, and

C=calorific value of the fuel per pound in heat units, then

$$E=\frac{42.63\times 60}{C\times F}$$

The thermal efficiency of the oil engine is low as compared with the gas engine. The best gas engine makers now claim a thermal efficiency for their engines of 27 per cent, whereas it is believed the maximum thermal efficiency recorded by any oil engine now in regular use is but 18 per cent.

DESIGN OF GAS AND OIL ENGINES.

Gas and oil engines should be of substantial design in order to withstand the continual shock and vibrations to which they are subject, and should be as accessible as possible in the working parts, which may require adjustment while in actual service. The starting gear and other parts to be handled by the attendant when starting and running the engines should be placed in close proximity to each other.

Simplicity in construction is the essential feature of a gas or oil engine. The oil engine is a machine intended for use in any part of the world where its fuel is obtainable, and where, perhaps, no mechanic is available. Accordingly, all the mechanism should be arranged so as to be easily removed for examination and repair. The igniting device, as well as the carbureter or vaporizer, should be so designed as to facilitate removal and repair. A gas or oil engine, to be successful mechanically and commercially, should be so designed that it can be successfully operated, cleaned and adjusted by unskilled attendants.

INSPECTING GAS OR OIL ENGINES.

Before examining an engine with a light, care should be taken that the combustion chamber is free from gas mixture. This can be done by turning the engine around a few times. The ignition should be cut out and the fuel supply cock closed. It is more or less dangerous to look down the chimney of the ignition tube when the engine is running.

It is sometimes necessary to inspect the interior of the engine cylinder with a lighted candle, for the purpose of locating some sharp projection, burnt carbon, crack or sand hole, etc. When doing this, always remember that a charge of fuel may remain in the cylinder, and whether the candle is inserted through one of the valve ports or the open end of the cylinder, be sure to keep the face away from the opening.

INSTALLING A GAS OR OIL ENGINE.

Secure the engine to a good foundation made according to the plans furnished by the engine builder.

Set up the water tank at any convenient distance from the engine, preferably as close as possible on the exhaust side. Use short pieces of rubber hose in the cooling tank piping. Put the shut-off valve close to the tank. Be sure that the vent pipe is long enough to be above the top of the tank. Water should always be at least 6 inches above the upper pipe or it will not circulate.

The water tank may be dispensed with by connecting a water feed pipe direct from a hydrant to the opening in exhaust valve chamber and running a waste pipe from top of cylinder jacket to carry off the water.

Regulate the amount of water by means of a stopcock placed in this pipe.

Keep the cylinder jacket just as hot as can be borne by the hand, say from 140 to 160 degrees Fahrenheit.

The fuel tank may be placed outside of the building and should be in a vertical position, twelve to eighteen inches lower than the top of the foundation, so that the fuel will flow from engine to tank. Care should be taken to wash out every piece of pipe with gasoline before connecting up, this removes all dirt and scale which would interfere with the proper working of the check valves. Extra care should be taken in making all water and fuel pipe connections tight. Use soap in the joints of the fuel pipes.

Run the exhaust pipe in any convenient direction, placing the muffler as near the engine as possible. Never use a pipe smaller than the opening in the muffler. Long and crooked runs should be avoided, but if necessary use a size larger pipe. It is not advisable to exhaust into a chimney.

Long vertical pipes collect water and should be connected with a Tee fitting at the bottom provided with suitable connections for draining.

Connect the battery cells with the spark coil, switch and binding posts on the engine. The ends of wires where the connections are made should have all the insulation removed and all nuts tightened well to insure good connections.

OIL ENGINE CYCLE.

The cycle or series of operations which take place in the vaporizing and combustion chambers of one of the usual forms of oil engine is illustrated in Figure 81. Before starting the engine the vaporizing chamber, shown to the left in the drawing, is brought to a red heat by means of a Bunsen burner, this heat being afterwards maintained by the combustion of the gases in the vaporizing chamber [illegible]

During the [illegible] stroke of the piston, a jet or spray of oil is [illegible] the opening in the nozzle at the bottom of the [illegible] chamber by means of a pump, and upon [illegible] with the hot interior of the chamber is [illegible]formed into vapor, at the same time a charge [illegible] is drawn into the cylinder of the engine [illegible] shown at the bottom of the combustion chamber. The piston then compresses the charge of air, forcing a portion of it into the vaporizing chamber and as soon as the explosive charge has reached the proper degree of temperature spontaneous or self-ignition takes place.

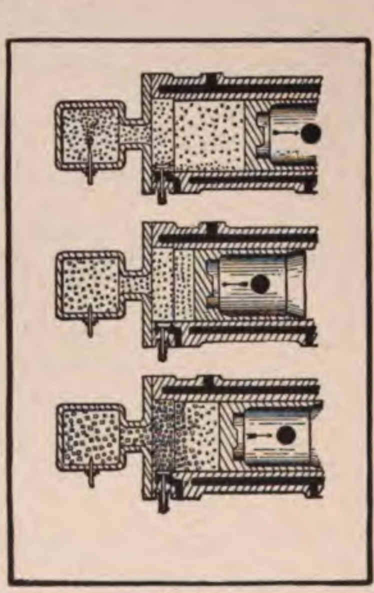


Fig. 81.
OIL ENGINE CYCLE.

OIL VAPORIZATION.

Oil engines have two methods of vaporization, one in which the oil is injected directly into the cylinder and the other where it is drawn in with the air. The mixture of oil vapor and air being carried on by compression in the cylinder, ignition is caused by an electric or tube igniter. The heat from the exhaust is sometimes utilized to raise the temperature of the chamber through which the oil passes to the cylinder, which, with the heat caused by compression, is sufficient to cause vaporization and a proper mixing with the air to form an explosive mixture, the chamber, which is heated by the exhaust in operation, being first heated by a burner.

The different types of vaporizers may be classed as follows:

A vaporizer into which the oil and all the air supply by a spraying nozzle connected to the combustion chamber through a valve.

A vaporizer into which the oil is injected, together with a small volume of air, the greater volume of air entering the cylinder through a separate valve.

A vaporizer into which the oil and all the air supply is drawn, but without a spraying device.

A form of vaporizer into which the oil is injected directly, air first being drawn into the cylinder by means of a separate valve, the explosive mixture being formed only with the compression.

OIL VAPORIZER.

On the Pacific coast crude oil is now largely used for fuel. In many instances the crude oil is vaporized in a separate apparatus and is then used in an ordinary gas engine. This apparatus is usually separate from the engine, the oil being entirely vaporized before it reaches the engine. Such vaporizing apparatus are made by various manufacturers, but in general principle they are similar. The heat of the exhaust gases from the engine is utilized to heat the vaporizer into which the crude oil is introduced, where it is converted into gas.

The fuel to be vaporized enters a ribbed chamber through suitable openings, and the gas is drawn from the chamber through a separate connection to the engine cylinder. The exhaust gases from the engine are connected to an outer chamber and pass around, heating the inner chamber to a temperature necessary for vaporization. Provision is made to draw off the residue of the crude oil, which is not capable of vaporization, and provision is also made to cleanse the vaporizing chamber of deposits of carbon and other incombustible matter.

The usual form of oil vaporizers consists of a heated chamber in which the charge of oil is transformed into vapor before being mixed with the air in the cylinder of the engine.

Vaporizers vary considerably in their construction and operation.

In some the oil strikes the air as it enters, in others a pump forces a jet of oil against the sides of the vaporizing chamber and is in this manner broken up into spray and mixed with the hot air, which rapidly vaporizes it.

A form of oil vaporizer is illustrated in Figure 82, in which the charge of oil is sprayed directly into the vaporizing chamber by means of a pump, the oil passing to the chamber through the small pipe shown in the left-hand view in the drawing.

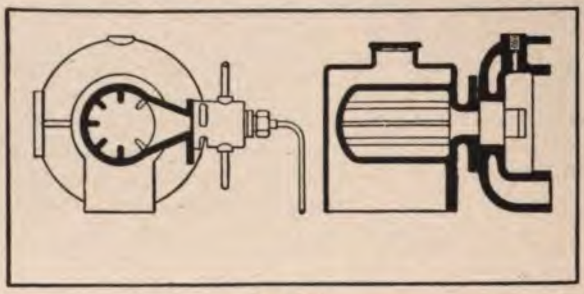


Fig. 82.

OIL ENGINE VAPORIZING CHAMBER WITH RIBS INSIDE.

REPAIRING A GAS OR OIL ENGINE.

The piston should be thoroughly washed with kerosene. When putting the piston back in the cylinder, each ring should be put separately in exact position in its groove as regards the dowel pin (if any) in the ring groove before the ring enters the cylinder. The piston, the rings, and the inside of the cylinder should all be carefully cleaned and well lubricated with proper oil before the piston is again put in place. Where the rings require cleaning, this should be done by washing with kerosene. If the piston-rings require to be taken off the piston, they should be sprung open by having pieces of sheet metal about one-sixteenth of an inch thick and about one-half inch wide inserted between the ring and the body of piston.

The inlet and exhaust-valves should be frequently taken out, cleaned and examined, and, if necessary, reground in. Finely -powdered emery or tripoli are very satisfactory to grind the valves in with.

Care should be taken, in replacing the valves, that they are clean and free from rust or carbon, and are allowed to drop on their seats freely and do not stick in their guides.

The crank-shaft bearings will occasionally require taking up as they show signs of wear and commence to knock or pound. For this adjustment, liners are placed between the cap and the lower half of the bearings. These liners can be occasionally reduced in thickness, so that the cap is allowed to come down closer to the shaft.

SUCCESSFUL OPERATION OF GAS OR OIL ENGINES.

Gas or oil engines are dependent for successful operation on two things: First, a charge of gas or vapor, mixed with sufficient air to produce an explosive mixture, and second, a method of firing the charge after it has been taken into the combustion chamber of the motor.

When coal or natural gas is used the supply is taken from the main and mixed directly with the necessary proportion of air. When gasoline or kerosene is used air is mixed with them in the correct proportion by carbureting devices.

The principal parts of a gas or oil engine are the cylinder, the piston, the piston-rings which fit into grooves in the piston: two sets of valves, one to admit the charge and the other to permit it to escape after the explosion, [illegible] crank shaft and connecting-rod which connect it with [illegible]n, and a flywheel, whose presence insures steady [illegible]f the motor, and whose further functions will [illegible]nderstood as the description proceeds. In the two-cycle form of gas or oil engine there is really but one valve, which is located in the crank case, the exhaust and admission-ports being covered and uncovered by the piston itself.

STARTING A GASOLINE OR KEROSENE ENGINE FOR THE FIRST TIME.

Don't attempt to start an engine the first time until the following points are found to be right:

That there is good compression.

That the batteries are set up properly and wired correctly.

That a good bright spark is obtained by touching the ends of the two wires at the engine together.

That there is a good supply of gasoline or oil in the supply tank.

That the gasoline or oil pump works freely and that the gasoline or oil reaches the vaporizer.

That the inlet and exhaust-valves are not stuck, and that they work freely and seat quickly.

STARTING A GAS OR OIL ENGINE, GENERAL DIRECTIONS FOR.

The successful starting or running of an engine depends entirely on the mixture of gas and air, and proper ignition.

As all of these are under full control of the operator at all times, it lies entirely with him as to whether the engine starts and runs properly or not.

The engine cannot start itself, it must be started.

If the above conditions and the following instructions are properly carried out, the engine will start without fail.

Before starting up the engine, go over all the connections carefully and see that everything is in place according to the instructions.

See that the gasoline tank is full.

Pump up the gasoline by working the pump lever until the feed chamber is full.

Close the cock in the bottom of the water tank and fill the tank to near the top pipe, but not full enough to run into the pipe if the weather is freezing.

Never let the water enter the cylinder or valve chamber jackets in cold weather until the engine has run long enough to become warm.

Open the burner-valve, first passing a nail or match down through a hole in the burner tube, and hold it so as to turn the stream of gasoline down and fill the burner pan, then close the valve and light the gasoline.

When the gasoline in the pan is burned out, open the valve and light the vapor, which should burn with a strong, steady blue flame.

The globe-valve, next to the burner, is to help regulate the flame, and should be closed nearly tight.

While the burner is heating the tube, which should take from two to three minutes, if it is properly regulated, see that the grease cups are full.

Oil up all parts of the engine. Fill the lubricator and start it to feed.

Turn the engine round by hand several times to see that everything is in its proper place, and nothing binding.

Examine the flywheel keys and see that they are driven tight.

When the tube is hot the engine is ready to start.

If electric ignition is used, close the battery switch. Almost close the air-valve before starting the engine.

The object of closing the air-valve is to obtain a rich charge and make it surer to explode.

The amount of fuel can be regulated at will.

It can be made so weak that it will not explode or so strong it cannot be ignited.

When black smoke issues from the exhaust pipe, the mixture is too strong.

STARTING A KEROSENE ENGINE.

The methods usually employed to ignite the explosive charge in the combustion chamber of an oil engine are: By means of an electric spark, an incandescent tube, or a vaporizing chamber with projecting ribs which are kept incandescent by the heat of the previous charge.

The proper heating of the vaporizing chamber is the first and most important thing to be attended to when starting an oil engine and care should be taken that the vaporizer is sufficiently hot before attempting to start the engine.

The Bunsen burner should be kept burning for five or ten minutes or even longer, according to the size of the engine. When the vaporizer is sufficiently heated, turn on the fuel oil supply and give the flywheels four or five quick turns, if all other conditions are right the engine should at once start. See that the cylinder lubricator and the oil cups on the crank shaft bearings are filled before starting the engine, also oil the wrist-pin end of the connecting-rod and the cam shaft bearings. After the engine is started, open the valve in the air-inlet pipe until the engine attains its normal speed.

When electric ignition is used, the battery switch should always be closed before an attempt is made to start the engine.

With the hot tube form of ignition, the tube should always be incandescent before starting the engine.

Always be sure that the supply of water to the cylinder jacket is ample.

With oil engines which operate on the vaporizer principle, it is found absolutely necessary to heat the fuel before it enters the cylinder. In some oil engines it is not necessary to heat the fuel before it enters the cylinder, as it is injected against a highly heated surface.

STARTING OIL ENGINES.

A method of starting an oil engine has of recent years been used in which alcohol, gasoline, or naptha is burnt for a few minutes instead of kerosene. This method is advantageous in that the engine when cold can be started without the use of an external heater. The lighter fuel is supplied to the vaporizer or cylinder until the vaporizing attachment has become heated by the internal combustion to the temperature necessary for vaporizing the heavier fuel, then the fuel supply is changed, the supply of lighter fuel being stopped. Where a vaporizer is used in which the charge is not explosive until after compression, an independent electric igniter is used to ignite the charge, and is only in operation until the vaporizer becomes properly heated.

STARTING TROUBLES.

If, after turning the flywheels of the engine four or five times, it refuses to start, the trouble may be due to any one of the following causes: Loss of compression, faulty ignition, improper mixture, water in the cylinder, or oil on the igniter contact-points.

Sometimes an engine will start readily, but dense smoke having a strong odor will issue from the exhaust-pipe. This may be an indication that the mixture is too rich, although it is frequently due to an excess of lubricating oil in the cylinder. To correct the mixture, more air should be admitted to the cylinder.

Failure of an engine to start is more often occasioned by too weak than by too rich a mixture. The first thing to do, if regulating the air does not correct it, is to ascertain if the fuel supply pipe is free from obstructions. This pipe is generally not very large, and is more or less crooked. A partial stoppage of the pipe will therefore result in a too weak mixture.

STOPPING A GAS OR OIL ENGINE.

The first things to do when stopping an engine are:

Shut off the gas or oil supply.

Close all oil cups or lubricators.

Switch off the battery or turn out the ignition tube burner.

Wipe off the engine and see that it is in good shape for the next run.

While cleaning the engine examine all nuts and bolts, all points needing adjustment. Examine the condition of the crank shaft and other bearings. If they are hot or show signs of heating, locate the cause if possible and [illegible] in starting the engine.

[illegible]w the battery switch off when the [illegible], as there is always a possibility of short circuiting the battery and possibly ruining it in a few hours.

It will pay to always keep the engine neat and clean. Examine the engine occasionally and see that everything is working properly.

If the engine has not to be re-started for some days, it is a good plan to turn off the oil supply to the cylinder for a short period before stopping, as what oil remains will be burnt out, and there is less liability of the gumming of the piston and cylinder or valves.

STOPPING TROUBLES.

Some of the principal causes of stopping of gas or oil engines are as follows:

Bad design or construction of the engine, improper mixture of fuel and air, defective water circulation or insufficient cooling of the cylinder, leakage of the piston, leakage of the valves or valve joints, improper or insufficient lubrication, governor gear defective, back pressure from fouling of the exhaust with residue, ignition mechanism worn or defective, imperfect compression or combustion, leak in the inlet-pipe, premature ignition, misfiring, backfiring, or the ignition wrongly timed.

STARTING A GAS ENGINE.

If an incandescent tube is used for the ignition, the Bunsen burner should first be lighted. While the tube is being heated, oil up all the working parts of the engine.

If electric ignition is used, close the battery switch.

Next, open the gas valve so as to admit a charge of gas into the inlet-valve chamber, along with the air, then give the flywheels four or five quick turns until the engine starts.

Open the lubricator on the cylinder and see that it is adjusted so as to allow about 10 drops of oil to flow per minute.

The water in the cooling tank should always be at least 6 inches above the overflow pipe from the top of the cylinder jacket.

If the engine does not ignite its first or second charge there is a reason for it, and the cause of the trouble should be located.

STARTING A GASOLINE ENGINE.

The instructions given for starting a gas engine apply also to a gasoline engine, with the exception that the supply of gasoline from the carbureter or mixing valve should be regulated according to the instructions given by the manufacturer of the engine.

The fuel supply of a gasoline engine is usually regulated by means of a needle-valve, which should be carefully cleaned at regular intervals. In engines using a pump feed, the supply of gasoline is usually regulated by adjusting the stroke of the pump, or by regulating the opening in a by-pass, so that a portion of the fuel is pumped through the by-pass and returns to the supply tank.

PORTABLE OIL ENGINES.

Portable gasoline and kerosene engines are used for a variety of purposes. Such engines in connection with circular saws, electric light or pumping outfits are found very useful. Portable engines are also used for agricultural work, such as operating threshing machines, feed cutters and other farm machinery. Figure 83 shows a portable oil engine mounted upon a truck with wooden frame and steel wheels and running gear. The engine, cooling apparatus and battery are clearly shown in the drawing.

As portable engines require to be frequently moved from place to place, the design of the outfit should be as light as possible and yet substantial in construction, so that it may be moved from one place to another in the shortest possible time and with the least expense for transportation.

As portable engines are often in places where a supply of water is not available, the water-cooling apparatus forms an important part of the outfit.

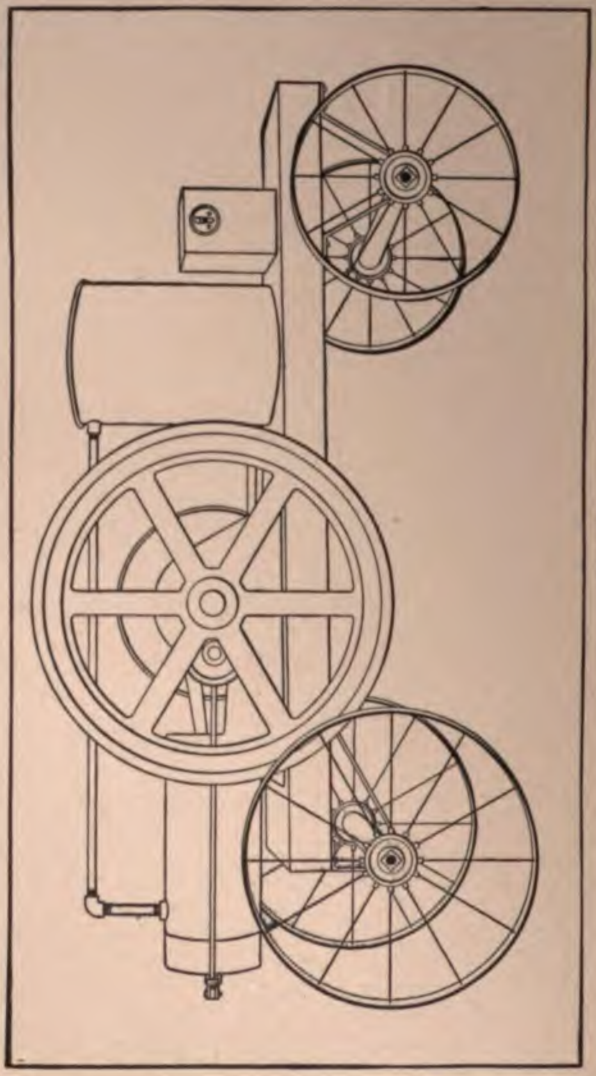


Fig. 83.

PORTABLE GASOLINE ENGINE FOR AGRICULTURAL WORK.

Another form of portable engine is shown in Figure 84, which is simply mounted on skids and may be moved from place to place by two persons. Such an outfit is of much smaller capacity than the one previously described and illustrated, but is found useful for many purposes where small power is needed.

FUEL CONSUMPTION OF GAS AND OIL ENGINES.

The fuel consumption of an engine is always one of grave importance to the purchaser, as well as to the manufacturer.

Ordinarily about 1 2-10 pints of gasoline or about 15 feet of natural gas, per horsepower per hour under full load, will cover the fuel consumption. That is, when the fuels used are of standard quality and the water comes from the water jacket at a temperature of about 140 to 160 degrees Fahrenheit.

The temperature of the water in the jacket around the cylinder has a great deal to do with fuel consumption.

To economize on the fuel consumption of an engine the following points should be observed:

1. To keep the jacket water at 160 degrees Fahrenheit.
2. To run the engine at a medium speed.
3. To use a good standard grade fuel.
4. To see that every charge the engine takes is exploded, for which a proper mixture and a good spark or hot tube are necessary.
5. The admission valve should close properly between charges, so as not to allow a continuous flow of fuel into the engine.
6. Never throttle the fuel so closely that the engine cannot get a full charge every time it needs it.
7. Be sure that there is no leak in the supply or overflow pipes where fuel can escape.
8. When gasoline or kerosene is used, be sure that there is no leak in the supply tank.

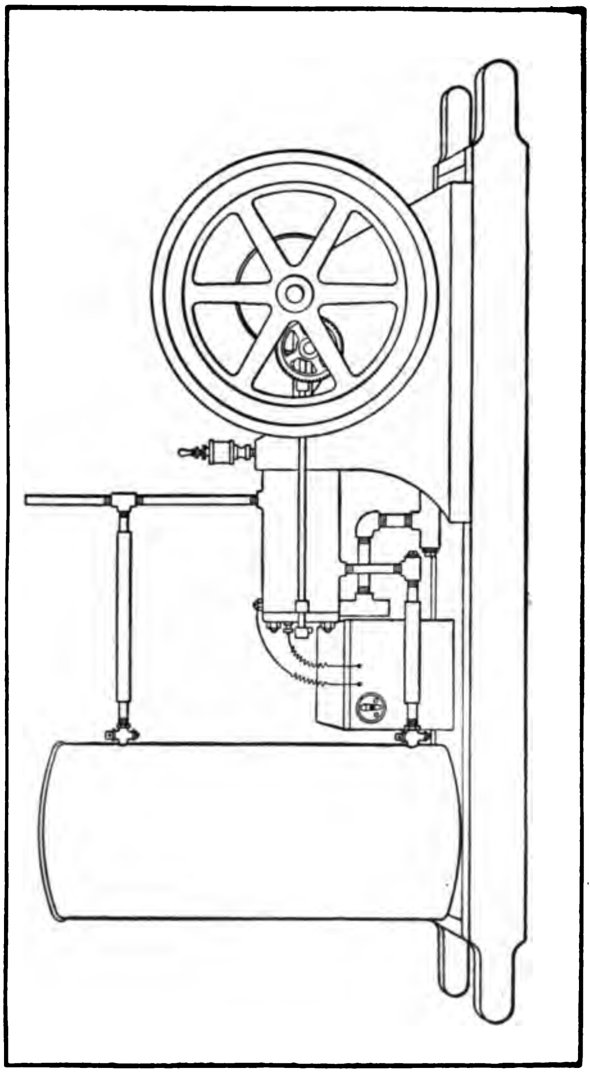


Fig. 84.

PORTABLE GASOLINE ENGINE MOUNTED ON SKIDS.

9. See that the exhaust and inlet valves seat properly and do not leak. The piston-rings should hold the pressure due to the explosion.

FUEL GAS OIL.

An oil known as fuel gas oil is procured in the process of fractional distillation after the lighter oils and the illuminating oils have been taken off. Tests of samples of this fuel gas oil, the characteristics of which vary considerably, are given in the following table:

FUEL-GAS OIL.

Specific gravity	**0.832**	**.878**
Beaumé	**36°**	**30.2°**
Flash-point	**144° F.**	**298°F.**
Firetest	**183° F.**	**247°F.**

This fuel is much used in oil engines in the United States. With the heavier grades a slight deposit of carbon is left in the engines, which requires periodical removing.

FLASH TEST OF OILS.

The apparatus used for this purpose consists of a small copper vessel in which the oil to be tested is placed. This vessel is immersed in a larger vessel containing water, which forms part of the upper portion of the apparatus.

A thermometer is suspended with its lower part in the oil. A heating lamp placed under the receptacle containing the water raises the temperature of both water and oil as required. A lighted taper is passed to and fro over the top of the oil as it becomes heated. When the vapor given off by the oil flashes the temperature is noted, and that is termed the flashing point of the oil tested.

CHAPTER XXIV.

GASOLINE MOTORS.

When explosive motors were first introduced the use of gasoline in connection with them had not been considered as a possibility. In later years, however, coal gas has been largely superseded by gasoline vapor, and gasoline motors are to-day far more common than gas motors. The principle of operation of the two are identical, however, and it should be understood that while gasoline motors are referred to, the description applies equally to gas motors.

In 1838 the first two-cycle gas motor was patented in England by William Barnett.

In 1862 Beau de Rochas formulated the cycle of operation of an explosive motor, as afterward built by Professor Otto, commonly known as the Otto four-cycle motor.

In 1876 the first practical working motor was introduced by Crossley Bros., of Manchester, England, under the patents of Professor Otto.

Explosive motors are of three forms, known as stationary, marine and automobile. Their general characteristics are implied by their various designations. The stationary motor may be either vertical or horizontal. Marine motors, designed for application to boats, are almost invariably vertical. Automobile motors are of comparatively recent introduction and of great variety, the aim of the designers being to secure the maximum of power and minimum of weight. They also may be vertical or horizontal.

These three forms may be again divided into two-cycle and four-cycle types. In the former an explosion occurs at every revolution. In the latter there is an explosion at every alternate revolution.

Explosive motors are dependent for successful operation on two things: First, a charge of gas or vapor, mixed with sufficient air to produce an explosive mixture, which is to the motor what air is to the lungs of a human being, and second, a method of firing the charge after it has been taken into the combustion chamber of the motor.

When coal gas is used the supply is taken from the main and mixed directly with the necessary proportion of air. When gasoline is used, air is mixed with it in the correct proportion by carbureting devices.

After the charge of gas and air has been taken into the cylinder it is compressed, as will be shown later, by the action of the motor itself and then fired, usually by an electric spark actuated by the motor, but sometimes by the use of a tube screwed into the cylinder and heated from the outside, the heat, of course, being communicated to the gas. The resulting explosion operates the motor.

The principal parts of a four-cycle explosive motor are the cylinder, the piston, the piston rings which fit into grooves in the piston; two sets of valves, one to admit the charge and the other to permit it to escape after the explosion: a crank shaft and connecting rod which connect it with the piston head and a flywheel, whose presence insures steady running of the motor, and whose further functions will be better understood as the description proceeds. In the two-cycle form of motor there is really but one valve, the exhaust and admission-ports being covered and uncovered by the piston itself.

All of the parts referred to are of the motor proper. Other parts, which are separate from the motor but on which its operation depends, are the carbureter, which supplies the charge of gasoline vapor and air for a gasoline motor, or a mixing chamber for mixing air and gas in the case of a gas motor, and the batteries and other parts of the electrical ignition device.

A part which has no connection with the actual running of the motor but with which practically all are fitted is the muffler, whose purpose is to deaden the sound of the explosion.

The cylinders of all except very small motors are as a rule partly encased in a chamber through which water is circulated, the object of this being to keep the cylinder cool.

The foregoing outline of the functions of the parts of the motor prepares us for a description of the two-cycle form of motor. This particular form of motor draws in a charge of gas or vapor, compresses it, fires it and discharges the product of combustion or burned gases while the crank makes but a single revolution and while the piston makes one complete travel backward and forward.

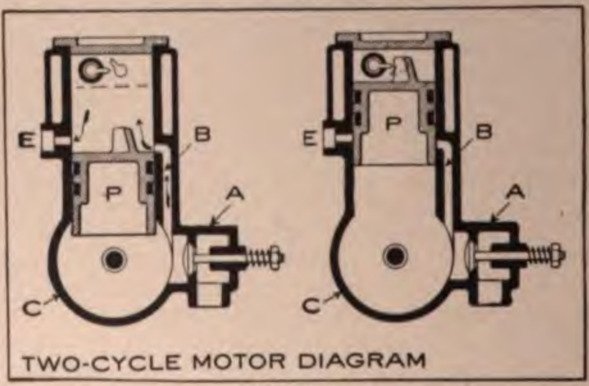


Fig. 85.
TWO-CYCLE MOTOR OPERATION.

Figure 85 shows two sectional views—that is to say, views of the motor cut in two, longitudinally—of the principal parts of a two-cycle motor. Other parts, such as the crank shaft, connecting rod and flywheel, are omitted to avoid confusion. C is the crank case and A the admission valve, through which the vapor passes to the crank case. B is the inlet passage, through which it passes from the crank chamber to the cylinder. P is the piston. The igniter, which makes the electric spark when the lower point comes in contact with the upper, is shown immediately below the cylinder cover. This causes the explosion of the vapor. E is the exhaust port, through which the burned charge escapes after the piston has been driven outward by the explosion and has reached the end of its stroke.

Let it be supposed that the motor is still and the crank chamber C is full of gas or vapor. To start the motor the piston is started by means of a crank on the flywheel shaft, and as it passes to the position shown in the left-hand drawing it forces the charge of vapor through the port B into the cylinder. The piston then returns to the position shown in the right-hand view, moving away from the crank chamber C, and in doing so closes the port B and the exhaust opening F, and compresses the charge of vapor. The points of the igniter come together, a spark occurs and the resulting explosion forces the piston outward again. When the piston reaches a point near the end of the stroke, as shown in the left-hand drawing, it uncovers the port E and the burned charge passes out, the new charge coming through the port B immediately afterwards.

The admission of the new charge to the crank chamber is controlled by the action of the piston. As the latter travels outward it has a tendency to create a vacuum in the crank chamber. This draws the valve inward and admits the charge of vapor.

It will be observed that there is a projection on the head of the piston. This is generally known as a baffle-plate. Its object is to prevent the incoming charge from passing directly across the cylinder and out at the exhaust port E, which, it will be observed, is directly opposite it. The baffle-plate directs the incoming charge toward the combustion chamber end of the cylinder, providing, as nearly as may be, a pure charge of vapor and assisting in the expulsion of the remainder of the burned gases remaining in the cylinder as a result of the last explosion.

Figure 86 furnishes two views of a four-cycle type of motor with some of the parts removed, as in Figure 85. It shows a cylinder C, admission-valve A, a piston P, and exhaust-valve E in place of the exhaust-port E in Fig. 85.

The left-hand view shows the piston P about to suck in a charge of vapor, by the same method as previously described, through the admission-valve A into the cylinder C. The suction continues until the piston P reaches the position shown in the right-hand view. Then the piston returns until it again arrives at the position shown in the left-hand view, compressing the charge of mixture during this operation. Just before the piston arrives at the end of its travel in this direction, the charge of vapor, now under compression, is ignited by the method previously explained and its expansion forces the piston back to the position shown in the right-hand view. When the piston has, for the second time, reached the position shown in the right-hand drawing, a mechanical device opens the exhaust-valve. The exhaust-valve remains open until the piston has again arrived at the position in the left-hand view. Then it closes, the piston again commences to draw in a charge of vapor, and the cycle is again repeated.

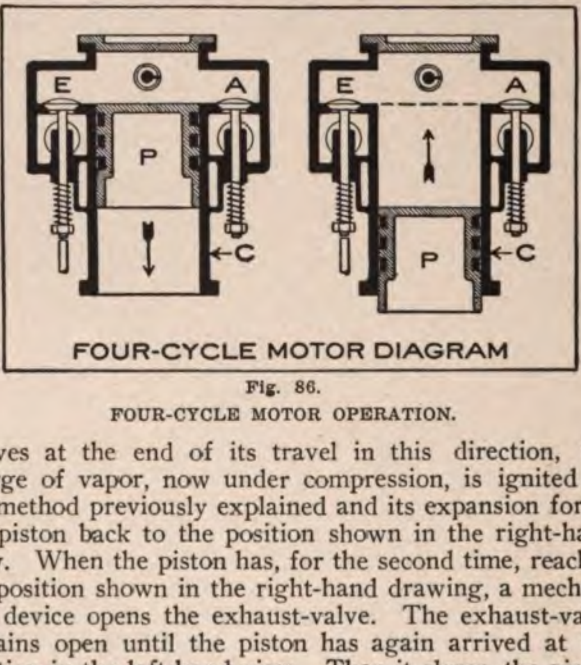


Fig. 86.
FOUR-CYCLE MOTOR OPERATION.

GASOLINE MOTOR CONSTRUCTION.

When designing a gasoline automobile motor, the first question that will arise is as to the proper number of cylinders. The question as to the proper number of cylinders for an explosive motor may be briefly summed up as follows: A single cylinder has the merit of simplicity, and requires less mechanism to operate it, but tends towards excessive vibration. Multi-cylinders develop more power with less weight and reduce the motor vibration and strain, and have also other advantages over a single cylinder. The question therefore is: How many cylinders are best in practice? To give the best results, a two-cylinder motor should, if the cranks are opposed, have its cylinders in axial alignment in order to ensure a uniform impulse. If the cranks and cylinders are opposed it is possible to obtain correct mechanical balance of connecting rods and pistons, and vibration is thus diminished. If the cylinders are of the twin form with the cranks opposed, explosions will necessarily follow each other at a half revolution, and one and a half revolutions apart. This gives irregular impulses which tend to set up vibration. The next best construction is three cylinders, with the cylinders parallel, and the cranks set at an angle of 120 degrees. This gives regular impulses two-thirds of a revolution apart, and consequently a more uniform strain on the parts, and reduces vibration.

A four-cylinder motor has greater advantages of mechanical balance than the three-cylinder form, but on the other hand, by reason of the greater amount of exposed cylinder wall for a given capacity, it is not as economical in fuel consumption. The greater advantage of four as compared with the three cylinders, is a greater division of the impulses, reducing vibration to a minimum.

Other points to be considered in the design of a motor are:

The proper arrangement or location of all working parts so as to be readily accessible for repair or adjustment.

Practically automatic lubrication of the motor.

The best and simplest method of operating the admission and exhaust-valves.

The proper diameter and weight of flywheel and a practically correct balance of the reciprocating parts of the motor.

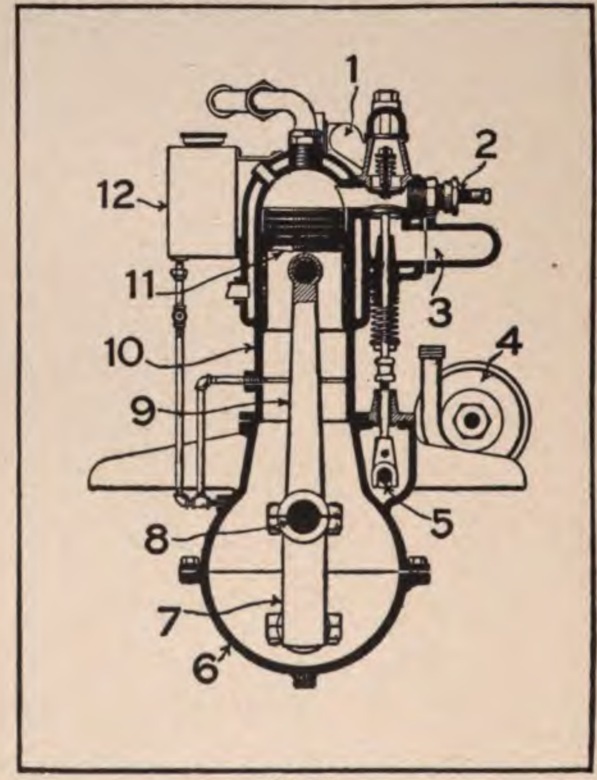


Fig. 87.

VERTICAL CROSS-SECTION OF A GASOLINE AUTOMOBILE MOTOR.

1. Admission valve.
2. Spark plug.
3. Exhaust valve.
4. Rotary pump.
5. Cam shaft.
6. Crank case.
7. Crank shaft.
8. Crank pin.
9. Connecting rod.
10. Cylinder.
11. Piston and rings.
12. Oil tank.

The best and most reliable system of ignition, with a view to eliminating ignition troubles.

The most economical type of carbureter and one that will require the least attention.

And last, but not least, reduction of weight, simplicity of construction and good mechanical design.

In the construction of motor cylinders experience has clearly established one point—that the cylinder, with its combustion and valve-chambers, should be integral or in one piece, and that no joints closed by gaskets should exist back of the head of the piston. While all manufacturers do not adhere to this rule, it is a fact that many difficulties have been experienced with leaky joints, and that the plan of avoiding them altogether should be followed.

Figure 87 shows a vertical cross-section of a gasoline automobile motor of the most approved modern type. It has automatic lubrication, detachable inlet or admission-valve and rotary pump for the water circulating system.

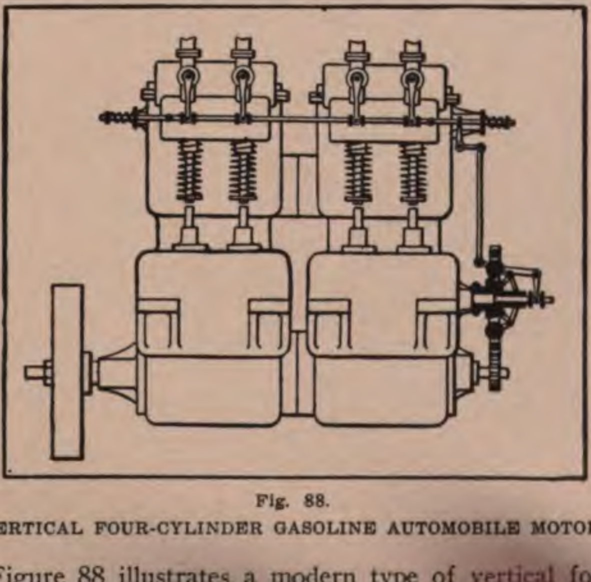


Fig. 88.

VERTICAL FOUR-CYLINDER GASOLINE AUTOMOBILE MOTOR.

Figure 88 illustrates a modern type of vertical four-cylinder gasoline automobile motor, having the admission-valves automatically throttled by means of [illegible] centrifugal governor on the end of the cam-shaft, as shown in the drawing. The admission-valves are mechanically operated.

While the cooling of the cylinder of an explosive motor is most successfully accomplished by means of a water-circulating system, a number of up-to-date cars successfully use cooling devices other than water. The success of air cooling for explosive motors is due in most cases to the use of a number of ribs cast integral with the cylinder and having a large radiating surface.

Figure 89 shows a form of vertical air-cooled motor with radiating ribs cast around the cylinder and valve-chamber. The motor has a detachable, atmospherically operated admission-valve, without packing. The valve and cage may be removed by simply removing two nuts.

CONNECTING-RODS.

Connecting-rods of gas and oil engines are of various shapes in cross-section, but those principally in use are made of steel with rectangular or circular section, with an adjustable bronze bearing at the crank-pin end.

The crank-pin end bolts should be so proportioned as to have an area of at least 25 per cent of the mean cross-section of the rod.

A connecting-rod of rectangular section, when made of steel, should have a cross-sectional area at least 30 per cent greater than the circular one. For a rod of circular section the width of the rod should be at least one-third its mean depth.

For small engines a good and cheap form of connecting-rod may be made of phosphor bronze or cast steel.

CRANK SHAFTS.

The crank shaft of a gas or oil engine should be made of sufficient strength not only to withstand the sudden pressure due to the explosion, but also to withstand the strain consequent upon the greater explosive pressure which may possibly be caused by previous missed explo-

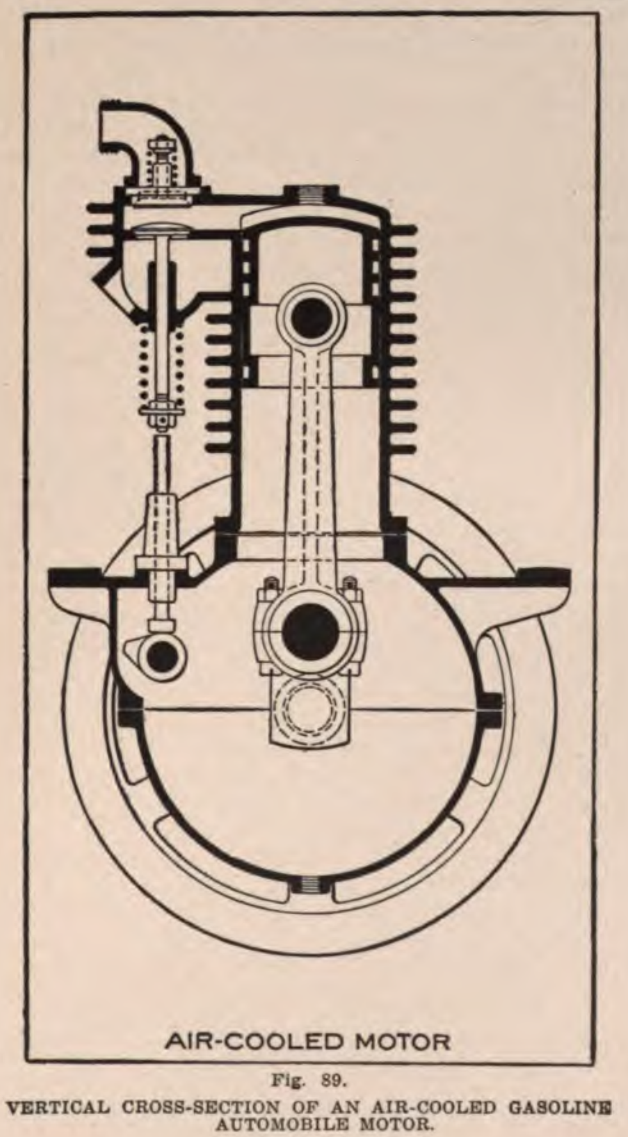


Fig. 89.

VERTICAL CROSS-SECTION OF AN AIR-COOLED GASOLINE AUTOMOBILE MOTOR.

sions. The crank shaft should be proportioned with relation to the area of the cylinder and the maximum pressure of the explosion.

The mechanical efficiency of an engine may be gauged by the strength of the crank shaft, because if the crank shaft is not sufficiently strong, it will spring at each impulse, causing the flywheels to run out of true and also wear the bearings unevenly.

The balancing of the crank shaft and reciprocating parts is an important feature of a gas or oil engine. With a single-cylinder explosive engine, to perfectly accomplish the balancing is impracticable. Most manufacturers, therefore, only balance their engines as far as the reciprocating parts are concerned.

Balancing by means of a recess in the rim of the flywheel has the advantage of requiring no extra metal, and is cheaper as regards workmanship as compared with the method of balancing the crank shaft by means of counterweights. In each of these methods, however, the flywheel itself is out of balance, and when rotating tends to make the crank shaft run out of true.

As it is important that the crank shaft be of ample strength, it is the best practice to make it of forged steel cut from the solid and finished bright all over. If the crank shaft be too weak, it will spring with the force of the explosions, thereby causing undue wear on the bearings.

FOUNDATION BOLTS.

The number and size of these are usually determ by the builder of the engine and indicated by the n ber of holes in the engine base. The bolts should be l enough to extend from the bottom of the foundation from two and a half to four inches above the capsto

They should have iron anchor plates at the bottom ar be threaded at the top to receive a nut.

FOUNDATIONS.

A concrete foundation, if properly constructed, is the best. While foundations are usually built of brick or stone laid in cement, a foundation may be of concrete, mixed as follows: One part of cement, two parts of coarse sand, five parts of fine crushed stone or coarse gravel.

It is desirable to have the capstone from 3 to 6 inches wider and longer than the base of the engine. The depth of the foundation will depend entirely upon the condition of the ground in the vicinity where the engine is to be set up.

The foundation should always go below the freezing line and as much below as is necessary to get a firm base. Ordinarily from 3 to 4 feet is sufficient for small engines from 4 to 12 horsepower. For larger engines from 15 to 40 horsepower, 4 to 6 feet is not too much.

Where possible, the sides of the foundation should have a slope or batter not less than 15 degrees.

PISTONS.

The piston used in a gasoline motor cylinder is of the single-acting or trunk type. It is made of an iron casting which is a good working fit in the cylinder. Around the upper end of the piston three or four grooves are cut, and in these grooves the piston-rings fit. The rings are made of cast iron, and the bore of the ring being eccentric to its outer diameter, there is a certain amount of spring in them, and so pressure is caused against the cylinder wall, preventing any of the expanding gases passing the piston.

The lubrication of the piston-rings is very important, for on that depends the proper working of the piston in the cylinder. In single-cylinder motors, the piston-rings require frequent attention, and kerosene should be injected into the spark plug opening at frequent intervals. Occasionally the cylinder should be taken off, and the rings cleaned with a brush and kerosene. In multi-cylinder motors, this constant attention is not required, for in addition to the splash system of lubrication, usually, there are pipes leading to the cylinders, through which oil is fed and so keeps them well lubricated. The speed of the motor being so much less, there is no danger of the oil being used up rapidly.

The piston displacement of a motor is the volume swept out by the piston, and is equal to the area of the cylinder multiplied by the stroke of the piston. The expression, cylinder volume, is sometimes confounded with the term piston displacement. This is erroneous, as the cylinder volume is equal to the piston displacement, plus the combustion space in the cylinder head.

For vertical cylinder motors the length of the piston should not on any account be less than its diameter, while a length equal to one and one-quarter or even one and one-third diameters is better. For motors with horizontal cylinders the length of the piston, in any case, should not be less than one and one-third diameters, and if possible one and one-half diameters or over.

To ensure proper compression, it is absolutely essential that the piston-rings should be kept lubricated; consequently when the motor has been idle for some time, the compression at the start is often poor. Any failure in the lubrication while running will, of course, have the same effect, such, for example, as in the case of overheating, or when the supply is intermittent. Sometimes the piston-rings get stuck in their grooves with burnt oil, through overheating, and the compression escapes past them. Thorough cleaning with kerosene and fresh lubricating oil will settle the matter. In motors where the rings are not pinned in position, the slots may work round so as to coincide. In this case they will have to be moved around. Sometimes burnt oil may, apparently, have the opposite effect on piston-rings, for by causing the piston to grip in the cylinder, it will produce considerable resistance, and the operator might erroneously think in consequence that his compression is good. In every case, after a long run, a little kerosene should be injected into the cylinders to clean the rings.

A pattern should be made from which to cast a blank cylinder or sleeve with two projecting slotted lugs on one end to bolt same to face plate of lathe. This blank should first be turned off outside to the required diameter, making it, of course, sufficiently larger to allow for the cut in the rings, after cutting from the blank. The blank should then be set over eccentric sufficiently to allow the thick side of the rings to be twice the thickness of the thin side after turning. The inside of the blank can then be bored out, and the rings cut off to the exact thickness required with a good sharp cutting off tool. A mandril or arbor should be made with two cast iron washers or collars to fit on it, one fastened to the mandril and the other loose, with lock nut on mandril with which to tighten up the loose collar. After the rings have been sawed open and a piece cut out the required length, they can be placed in a collar or ring about 1-32 to 3-64 of an inch larger than the cylinder bore, and slipped on to the mandril one at a time of course, with the loose collar and nut off the same. The loose collar and nut can then be put on the mandril, the ring clamped tightly between the two collars, the mandril put in the lathe and the ring turned off, without leaving any fins or having to cut the ring off afterward as is done in many cases. This is the only way in which a perfectly true ring can be made.

The speed of rotation of an explosive motor is limited by the fact that the velocity of the piston must be considerably less than the rate of combustion of the explosive mixture, in order that the motor may develop energy or do work. The practical limit of piston velocity is said to be between 14 and 16 feet per second.

STARTING A GASOLINE MOTOR.

The most important point about starting a gasoline motor is to ascertain if the cock in the supply pipe leading from the gasoline tank is open. Failure to do this has caused the display of more temper, profanity and anxiety than any other detail, except that of forgetting to close the switch before cranking the motor. Another point is to see that the tank has been previously filled with gasoline.

Next flush the carbureter to see if the gasoline flows from the tank, then give the motor one or two turns by means of the starting-crank and with the compression-release cock—if any—open. If a mechanical feed or splash lubrication is used, there will be no necessity to look after the lubrication, but if a gravity oil feed is used, do not forget to turn on the oil before starting the motor.

Never forget to retard the ignition before starting the motor. A back fire will result if this precaution is neglected, and a nasty blow, or even a broken wrist or arm may be the result. The proper way to avoid this trouble is to have the ignition lever spring-controlled so that the ignition is always retarded when the motor is not running.

STARTING TROUBLES.

If the motor refuses to start, the trouble may be due to oil or grease on the spark plug points; this may be remedied without removing the plug, by disconnecting the secondary wire from the plug and placing it near the terminal, so as to allow an external and visible spark to occur. Once the motor is started the oil gets burned up by the heat, so that ignition will continue after a permanent connection of the secondary wire has been made. Generally it is necessary to stop the motor, or at least the spark, to facilitate re-connecting the wire without receiving a shock, but if the motor is hot it will re-start easily. This is merely a temporary adoption of the extra spark gap.

Sometimes the motor will start readily, but dense smoke having a strong odor will issue from the muffler. This may be an indication that the mixture is too rich, although it is frequently due to an excess of lubricating oil in the cylinder. To correct the mixture, more air should be admitted to the carbureter.

Failure of the motor to start is more often occasioned by too weak than by too rich a mixture. The first thing to do, if regulating the air does not correct it, is to ascertain if the gasoline pipe is free from obstruction. This pipe is not large, and is more or less crooked A partial stoppage of the pipe will therefore result in a too weak mixture.

Water in the carbureter is not an infrequent cause of the motor failing to start. All gasoline contains more or less water, which, being heavier than the gasoline, settles at the bottom of the supply tank and finds its way to the carbureter. If the pet-cock at the botom of the carbureter be opened, the water—which will have collected in the lowest part of the carbureter—will pass out with the gasoline.

STOPPING A GASOLINE MOTOR.

The first things to do after stopping the motor are:

Shut off the battery switch, and remove the plug.

Close all oil cups or lubricators.

Shut off gasoline if there is no float in the carbureter.

In the winter and if the car will be in a cold place, drain off the water from the circulating system.

Wipe off the motor, and see that it is ready for the next run.

When cleaning the motor examine all bolts and nuts, and all points needing adjustment.

Note the condition of the journals and bearings, if they are hot ascertain the cause of heating.

VALVES.

[illegible] valve in a very bad or pitted condition causes bad [illegible]ssion and the exhaust-valve should be ground [illegible]nally. After grinding the exhaust-valve be sure [illegible] ample [illegible]rance between the valve and the [illegible] [illegible]ot less than one-thirty-second [illegible]en the valve becomes hot it will not seat properly, poor compression being the result. In grinding a valve there is no occasion to use force, and the grinding should be done lightly, the valve being lifted from time to time so that any foreign substance in the emery will not cut a ridge in the seat or the valve itself. After grinding the valve always wash out the valve seat with a little kerosene and be careful that none of the emery is allowed to get into the motor cylinder.

Valves which need reseating should first be ground in place with fine emery and oil, then finished with tripoli and water.

Sometimes a motor may suddenly stop from the failure of the exhaust-valve to seat properly. This may be due to the warping of the valve through the motor having run dry and become hot, or it may be from the failure of the valve spring or the sticking of the valve-stem in its guides. The valve should be removed, and the stem cleaned and scraped, or straightened if it requires it, until it moves freely in the guide, and the spring is given its full tension. If the valve still leaks so that the motor will not start or develop sufficient power, the valve will have to be ground into its seat.

It has been determined from the result of experiments that to get the maximum power at any speed from a gasoline motor equipped with a float-feed carbureter, the jet of the carbureter must have a larger opening for low speeds than for high speeds. As this practice would require a very delicate adjustment it consequently becomes almost impracticable, because necessitating a constantly varying regulation for each fractional variation of speed of the motor. The difficulty may be obviated by the use of an auxiliary air-valve, located in the induction-pipe close to the inlet-valve of the motor.

The jet of the carbureter is set for the maximum quantity of gasoline at the slowest speed of the motor, and as the speed is increased the auxiliary air-valve comes into action and reduces the supply of air passing through the carbureter, thereby reducing the suction of partial vacuum at this point, and maintaining a constant quality of mixture at all times.

Recent experiences call attention to the fact that a change is necessary in the construction of valves, or rather that part of the valve attachments adopted, by some designers, to hold the spring in position. This remark applies particularly to the vertical type of valve, but the same defect has been found in horizontal valves. Opinions vary as to the best method of securing the springs in position, some designers preferring pins, either round or square, others the nut and cotter. Both have points in their favor and some common faults. It is doubtful, however, whether the method of slotting or broaching the stem and then using a key for securing the spring, is as secure as that of using a nut and pinning it to prevent its becoming loose. Under the latter plan there is no drilling of the stem except for a small cotter or split-pin and the nut carries the strains, whereas in the other method the strain bears on the stem at the point at which the slot is made for the key, the latter being the means by which the strain is carried to the stem. Especially is the slotting of the stem unsafe when the stem is hardened, for vibration plays havoc with the valve. Many breakages have occurred from this cause and the question has become serious. While it is a fact that both kinds have suffered, the nut method of fastening is to be preferred, from the fact that even though the split pin may break and drop out, and the nut become loose, the trouble can be temporarily remedied by an extra piece of wire, while the slotted stem breaks off at a point where the metal is thinnest and makes the valve useless.

The movement of the valves should always be timed to give the proper results. This is an important point to remember. The exhaust-valve cam shaft on a four-cycle motor is usually driven by the two to one gear on the crank shaft, and if for any reason the gears are taken apart and put together, even if only one tooth is out of place, it will throw the valve and spark mechanism out of time.

To ascertain if the exhaust-valve of a motor is properly timed, turn the flywheel over slowly and notice at he next in

pression stroke, when both val

CHAPTER XXV.

HORSEPOWER.

ENERGY.

A standard horsepower is the amount of energy that will raise a weight of 33,000 pounds one foot high in a minute, or 550 pounds one foot high in one second. An engine or motor exerting one actual horsepower will raise a weight of 10 pounds 3,300 feet in one minute, but will require 10 minutes to raise 330,000 pounds one foot high.

The heat energy of fuel is measured theoretically on the following basis: If a pound weight fall 780 feet in a perfect vacuum it would generate heat energy sufficient to raise the temperature of one pound of water, one degree Fahrenheit. The heat energy required to convert one pound of water at a temperature of 32 degrees Fahrenheit into steam at atmospheric pressure, would lift a weight 2,000 pounds 400 feet high in one minute, or develop two-fifths of one horsepower for one hour.

ANIMAL POWER.

A horse can exert a full horsepower hour for only six hours a day. One mechanical horsepower is therefore equivalent to the work of four horses.

The average work of a good horse may be rated at 22,500 pounds raised one foot high in a minute for eight ours a day. A draft-horse can draw a load of 1,600 unds 25 miles per day on a good road, weight of the cle included.

[illegible] man can exert a force of 30 pounds for 10 hours a [illegible] hich is equivalent to 4,500 pounds raised one foot [illegible] minute, or two-fifths the work of a horse.

A man can travel, without a load, on the level, for 8½ hours a day, at the rate of 3½ miles an hour, or 30 miles a day.

A man carrying a load a short distance and returning unloaded, can carry 135 pounds, 7 miles a day. A man can transport in a wheelbarrow, 150 pounds, 10 miles a day.

HORSEPOWER.

Horsepower is of three kinds: calculated, actual or brake, and indicated horsepower. Calculated horsepower is always greatly in excess of actual or brake horsepower, as heat and friction losses do not enter into consideration in the formulas used.

Actual or Brake horsepower is obtained by the use of a Prony brake, so called after its inventor. This simple device gives the actual energy in foot-pounds per minute, delivered at the driving shaft.

Indicated horsepower represents the actual thermodynamic (heat pressure) conditions within the engine cylinder, but does not take into account friction or other external power losses.

CALCULATED HORSEPOWER.

The factors entering into the calculation of the horsepower of a steam engine or an explosive motor are, the effective temperature of the charge in the cylinder as indicated by the average pressure throughout the piston stroke, the cubic contents of the cylinder, which are given by the length of the stroke and the area of the piston, and the number of working strokes or impulses per minute.

The product of these factors, which is found by multiplying them together, will give the available energy in foot-pounds per minute. This product, divided by 33,000, gives the horsepower required.

To ascertain the horsepower when the average pressure upon the piston in pounds per square inch is known:

Find the area of the piston in square inches, by multiplying the square of its diameter by 0.7854.

Find the total pressure in pounds on the piston by multiplying the area by the average effective pressure in pounds per square inch. The average effective pressure is the average pressure in pounds per square inch less 14.7, which must be deducted to allow for the atmospheric pressure against the piston.

Find the useful piston travel in feet per minute by multiplying twice the length of the piston stroke in feet by the number of revolutions per minute of the crank shaft, for a double-acting steam engine, or by the number of working impulses per minute for an explosive motor. Find the energy in foot pounds per minute by multiplying the total pressure in pounds on the piston by the useful piston travel in feet per minute.

The horsepower may then be ascertained by dividing the energy in foot-pounds per minute by 33,000.

While there are numerous formulas in use for calculating the horsepower of an engine, one of the most simple is as follows:

$$HP=\frac{P\times L\times A\times N}{33{,}000} \qquad (1)$$

Where P is the average effective pressure in pounds per square inch, L twice the length of the piston stroke in feet, A the area of the piston in square inches, N the number of revolutions of the crank shaft per minute and HP the horsepower.

Example: What horsepower will a steam engine of 4-inch bore and 6-inch stroke develop at 300 revolutions of the crank shaft per minute, cutting off at one-third stroke and having an initial pressure of 150 pounds per square inch?

Answer: The average pressure from Table No. 3 corresponding to 150 pounds initial pressure, with one-third cut-off, is 104.9 pounds. From this must be deducted 14.7 pounds, which represents the back [illegible] pheric pressure in the case of a single expansion [illegible] giving 90.2 pounds as the [illegible]rage effective pre[illegible]

TABLE NO. 3.—AVERAGE STEAM PRESSURE ON PISTON, IN POUNDS PER SQUARE INCH.

	Average Pressure throughout the Piston Stroke. Initial Pressure = 1.	.966	.937	.919	.846	.743	.699	.596	.385
	Number of Volumes to which the Steam is Expanded.	1⅓	1½	1⅗	2	2⅔	3	4	8
	Point of cut-off.	¾	⅔	⅝	½	⅜	⅓	¼	⅛
Initial Pressure in Pounds per Square Inch.	50	48.2	46.7	45.9	42.3	37.1	35.0	29.8	19.2
	55	53.0	51.3	50.5	46.6	40.8	38.4	32.8	21.2
	60	57.8	56.0	55.1	50.8	44.5	41.9	35.8	23.1
	65	62.8	60.7	59.7	55.0	48.2	45.4	38.8	24.9
	70	67.5	65.3	64.3	59.2	52.4	48.9	41.6	26.7
	75	72.3	70.0	68.9	63.5	56.1	52.4	44.7	28.6
	80	77.1	75.7	73.5	67.7	59.3	55.9	47.7	30.8
	85	81.9	80.3	78.1	72.0	63.0	59.4	50.7	32.7
	90	86.7	84.0	82.7	76.2	66.8	62.9	53.7	34.6
	95	91.5	88.7	87.3	80.4	70.4	66.4	56.7	36.6
	100	96.4	93.3	91.9	84.6	74.2	69.9	59.6	38.5
	105	101.2	98.0	96.5	88.9	77.9	73.4	62.6	40.4
	110	106.0	101.7	101.0	93.1	81.6	76.9	66.6	42.3
	115	110.8	106.3	105.6	97.4	85.2	80.4	69.6	44.2
	120	115.6	112.0	110.2	101.6	89.0	83.9	71.6	46.2
	125	120.5	115.7	114.8	105.8	102.8	87.4	74.6	48.1
		1	2	3	4	5	6	7	8

TABLE No. 3.—AVERAGE STEAM PRESSURE ON PISTON, IN POUNDS PER SQUARE INCH. (CONTINUED)

	Average Pressure throughout the Piston Stroke. Initial Pressure = 1.	.966	.937	.919	.846	.743	.699	.596	.385
	Number of Volumes to which the Steam is Expanded.	1⅓	1½	1⅗	2	2⅔	3	4	8
	Point of cut-off.	¾	⅔	⅝	½	⅜	⅓	¼	⅛
Initial Pressure in Pounds per Square Inch.	130	125.3	121.3	119.4	110.0	96.4	90.9	77.5	59.8
	140	134.9	130.7	128.6	118.5	103.8	97.9	85.3	53.9
	150	144.6	139.3	137.8	126.5	111.3	104.9	89.5	57.7
	160	154.2	151.3	147.0	135.4	118.7	111.8	95.4	61.6
	170	163.8	160.7	156.2	143.9	126.1	118.8	101.4	65.4
	180	173.5	168.0	165.4	152.4	133.5	125.9	107.4	69.3
	190	183.1	177.3	174.5	190.8	140.9	132.8	113.3	73.1
	200	192.8	186.7	183.8	169.3	148.4	139.0	119.3	77.0
	210	202.4	195.0	192.9	177.8	154.8	146.8	125.3	80.8
	220	212.0	203.3	202.1	186.2	163.2	153.8	133.2	84.6
	230	221.6	212.7	211.3	194.7	170.4	160.8	139.2	98.5
	240	231.3	224.0	220.5	203.2	178.1	167.8	143.2	92.4
	250	240.9	233.3	229.7	211.6	185.4	174.7	149.1	96.2
	260	250.6	242.7	238.9	220.1	192.9	181.8	155.1	99.7
	280	269.8	261.3	257.2	237.0	207.7	195.7	170.6	107.8
	300	289.1	280.0	275.6	254.0	222.5	208.7	179.0	115.5
		1	2	3	4	5	6	7	8

square inch on the piston. From Table No. 2 the area of a circle 4 inches in diameter is 12.57 square inches, and twice the length of the piston stroke in feet is equal to one foot, then

$$HP=\frac{90.2\times 1\times 12.57\times 300}{33,000}=10.31 \text{ horsepower.}$$

The following formulas, Nos. 2, 3, 4 and 5, are merely transpositions of Formula No. 1, but will be found very useful in ascertaining the value of any one of the five factors in Formula No. 1, when the other four are known.

$$P=33,000\frac{HP}{L\times A\times N} \qquad (2)$$

Where P is the average effective pressure on the piston in pounds per square inch.

Example: What is the average effective pressure on the piston of an engine, with a cylinder 12 inches in diameter and piston stroke of 18 inches, the number of revolutions of the crank shaft being 100 per minute, and the horsepower 40?

Answer: As the area corresponding to 12 inches diameter is 113.09, or in round numbers, 113, then by Formula No. 2.

$$P=33,000\frac{40}{3\times 113\times 100}=38.9 \text{ pounds.}$$

To ascertain the required length of the piston stroke in feet, when the other terms in the equation are known:

$$L=33,000\frac{HP}{P\times A\times N} \qquad (3)$$

Where L is equal to twice the length of the piston stroke in feet.

Example: An engine is required to develop 40 horsepower, with 38.9 pounds average effective pressure per square inch on a piston 12 inches in diameter and a speed of the crank shaft of 100 revolutions per minute. What should be the length of the piston stroke?

Answer: The average effective pressure being 38.9 pounds, then by Formula No. 3,

$$L=33{,}000\frac{40}{38.9\times 113\times 100}=3.0 \text{ feet.}$$

Giving a piston stroke of 18 inches.

To find the required cylinder diameter, other conditions being as before stated:

$$A=33{,}000\frac{HP}{P\times L\times N} \qquad (4)$$

Where A is the area of the cylinder in square inches.

Example: An engine is required to develop 40 horsepower with an average effective pressure on the piston of 38.9 pounds per square inch. The length of the stroke is 18 inches and the speed of the engine crank shaft is 100 revolutions per minute, what should be the cylinder diameter?

Answer: The area of the cylinder by Formula No. 4 is, therefore

$$A=33{,}000\frac{40}{38.9\times 3\times 100}=113.1 \text{ square inches.}$$

And from Table No. 2, the nearest diameter corresponding to an area of 113.1 square inches is 12 inches.

The speed of the crank shaft of an engine may be readily ascertained from Formula No. 5, that is, if N be the speed of the crank shaft of the engine in revolutions per minute, then

$$N=33{,}000\frac{HP}{P\times L\times A} \qquad (5)$$

Example: What should be the speed of the crank shaft of an engine with a cylinder of 12-inch bore and 18-inch piston stroke, to develop 40 horsepower with an average effective pressure of 38.9 pounds per square inch on the piston?

Answer: The speed of the crank shaft of the engine in revolutions per minute by Formula No. 5, will therefore be

$$N=33{,}000\frac{40}{38.9\times3\times113}=100 \text{ revolutions per minute.}$$

The following formula may be used in place of Formula No. 1, if so desired

$$HP=\frac{P\times L\times D^2\times N}{42{,}000} \qquad (6)$$

Where D is the diameter of the piston in inches, the remainder of the terms used being the same as in Formula No. 1.

Example: Calculate the horsepower of the same engine by Formula No. 6.

Answer: As the square of the diameter of the piston is $4\times4=16$, then

$$HP=\frac{90.2\times1\times16\times300}{42{,}000}=10.31 \text{ horsepower.}$$

On the basis of these formulas, two simple rules may be derived for calculating the horsepower of a steam engine:

1. The horsepower is equal to the average effective pressure in pounds per square inch, multiplied by twice the piston stroke in feet, by the area of the piston in square inches and by the number of revolutions of the crank shaft per minute, divided by 33,000.
2. The horsepower is equal to the average effective pressure in pounds per square inch, multiplied by twice the piston stroke in feet, by the square of the diameter of the piston in inches and by the number of revolutions of the crank shaft per minute, divided by 42,000.

It should always be borne in mind that 14.7 pounds must in any case be deducted from the average pressure to obtain the average effective pressure on the piston, whether the average pressure is obtained from an indicator diagram, from Table No. 3, or from Formula No. 2.

Table No. 4.—Areas of Circles from 3 to 19¾.

Diameter.	Area of Circle.	Diameter.	Area of Circle.	Diameter.	Area of Circle.	Diameter.	Area of Circle.
3	7.07	5½	23.76	10	78.54	15	176.71
3⅛	7.67	5⅝	24.85	10¼	82.52	15¼	182.65
3¼	8.30	5¾	25.97	10½	86.59	15½	188.69
3⅜	8.95	5⅞	27.11	10¾	90.76	15¾	194.83
3½	9.62	6	28.27	11	95.03	16	201.06
3⅝	10.32	6¼	30.68	11¼	99.40	16¼	207.39
3¾	11.04	6½	33.18	11½	103.87	16½	213.82
3⅞	11.79	6¾	35.78	11¾	108.43	16¾	220.85
4	12.57	7	38.48	12	113.10	17	226.98
4⅛	13.36	7¼	41.28	12¼	117.86	17¼	233.71
4¼	14.19	7½	44.18	12½	122.72	17½	240.53
4⅜	15.03	7¾	47.17	12¾	127.68	17¾	247.45
4½	15.90	8	50.26	13	132.73	18	254.47
4⅝	16.80	8¼	53.46	13¼	137.89	18¼	261.59
4¾	17.72	8½	56.74	13½	143.14	18½	268.80
4⅞	18.66	8¾	60.13	13¾	148.49	18¾	276.12
5	19.64	9	63.62	14	153.94	19	283.53
5⅛	20.63	9¼	67.20	14¼	159.48	19¼	291.04
5¼	21.65	9½	70.88	14½	165.13	19½	298.65
5⅜	22.69	9¾	74.66	14¾	170.87	19¾	306.35

TABLE No. 5.—SQUARES OF DIAMETERS FROM 3 TO 19¾.

Number.	Square of Number.	Number.	Square of Number.	Number.	Square of Number.	Number.	Square of Number.
3	9.00	5½	30.25	10	100.00	15	225.00
3⅛	9.77	5⅝	31.64	10¼	105.06	15¼	232.56
3¼	10.56	5¾	33.06	10½	110.25	15½	240.25
3⅜	11.39	5⅞	34.52	10¾	115.56	15¾	248.06
3½	12.25	6	36.00	11	121.00	16	256.00
3⅝	13.14	6¼	39.06	11¼	125.56	16¼	264.06
3¾	14.00	6½	42.25	11½	132.25	16½	272.25
3⅞	15.016	6¾	45.56	11¾	138.06	16¾	280.56
4	16.00	7	49.00	12	144.00	17	289.00
4⅛	17.02	7¼	52.56	12¼	150.06	17¼	297.56
4¼	18.06	7½	56.25	12½	156.25	17½	306.25
4⅜	19.14	7¾	60.06	12¾	162.56	17¾	315.06
4½	20.25	8	64.00	13	169.00	18	324.00
4⅝	21.39	8¼	68.06	13¼	175.56	18¼	333.06
4¾	22.56	8½	72.25	13½	182.25	18½	342.25
4⅞	23.77	8¾	76.56	13¾	189.06	18¾	351.56
5	25.00	9	81.00	14	196.00	19	361.00
5⅛	26.27	9¼	85.56	14¼	203.06	19¼	370.56
5¼	27.56	9½	90.25	14½	210.25	19½	380.25
5⅜	28.89	9¾	95.06	14¾	217.56	19¾	390.06

Areas of circles and squares of diameters from 3 to 15¾ are given in Tables No. 4 and 5. These are intended for use in connection with Formulas 1 to 10.

Formulas No. 7, 8, 9 and 10 are, as in the case of Formulas 2, 3, 4 and 5, for the purpose of obtaining the average effective on the piston, the revolutions per minute of the crank shaft of the engine, the diameter of the cylinder or piston, and the piston stroke in feet being given, then

$$P = 42{,}000 \frac{HP}{L \times D^2 \times N} \qquad (7)$$

Where P is the average effective pressure on the piston in pounds per square inch,

$$L = 42{,}000 \frac{HP}{P \times D^2 \times N} \qquad (8)$$

Where L is equal to twice the piston stroke in feet

$$D^2 = 42{,}000 \frac{HP}{P \times L \times N} \text{ and}$$

$$D = 204.9 \sqrt{\frac{HP}{P \times L \times N}} \qquad (9)$$

Where D is the diameter of the cylinder or piston in inches, and

$$N = 42{,}000 \frac{HP}{P \times L \times D^2} \qquad (10)$$

Where N is the number of revolutions of the crank shaft of the engine per minute.

POINT OF CUT-OFF.

As steam is ordinarily admitted to the cylinder of an engine by the valve for only a portion of the piston stroke, more pressure and consequently more power can be obtained from a steam engine, by allowing the full boiler pressure to communicate with the cylinder for 80

TABLE No. 6.—NATURAL LOGARITHMS OF NUMBERS—1 to 30.

No.	Natural Log.	No.	Natural Log.	No.	Natural. Log.	No.	Natural Log.
1.01	0.009	2.25	0.811	3.50	1.253	4.75	1.558
1.05	0.049	2.30	0.833	3.55	1.267	4.80	1.569
1.10	0.095	2.35	0.854	3.60	1.281	4.85	1.579
1.15	0.139	2.40	0.876	3.65	1.295	4.90	1.589
1.20	0.182	2.45	0.896	3.70	1.308	4.95	1.599
1.25	0.223	2.50	0.916	3.75	1.321	5.00	1.609
1.30	0.262	2.55	0.936	3.80	1.335	5.05	1.619
1.35	0.300	2.60	0.956	3.85	1.348	5.10	1.629
1.40	0.336	2.65	0.975	3.90	1.361	5.15	1.639
1.45	0.372	2.70	0.993	3.95	1.374	5.20	1.649
1.50	0.405	2.75	1.012	4.00	1.386	5.25	1.658
1.55	0.438	2.80	1.029	4.05	1.399	5.30	1.668
1.60	0.470	2.85	1.047	4.10	1.401	5.35	1.677
1.65	0.501	2.90	1.065	4.15	1.423	5.40	1.686
1.70	0.530	2.95	1.082	4.20	1.435	5.45	1.696
1.75	0.559	3.00	1.098	4.25	1.447	5.50	1.705
1.80	0.588	3.05	1.115	4.30	1.459	5.55	1.714
1.85	0.615	3.10	1.134	4.35	1.470	5.60	1.723
1.90	0.642	3.15	1.147	4.40	1.482	5.65	1.732
1.95	0.668	3.20	1.163	4.45	1.493	5.70	1.741
2.00	0.693	3.25	1.179	4.50	1.504	5.75	1.749
2.05	0.718	3.30	1.194	4.55	1.515	5.80	1.758
2.10	0.741	3.35	1.209	4.60	1.526	5.85	1.766
2.15	0.765	3.40	1.224	4.65	1.537	5.90	1.609
2.20	0.788	3.45	1.238	4.70	1.548	5.95	1.78

TABLE NO. 6.—NATURAL LOGARITHMS OF NUMBERS—1 to 30. CONTINUED.

No.	Natural Log.	No.	Natural Log.	No.	Natural. Log.	No.	Natural Log.
6.00	1.792	7.25	1.981	8.50	2.140	9.75	2.277
6.05	1.800	7.30	1.988	8.55	2.145	9.80	2.282
6.10	1.808	7.35	1.995	8.60	2.152	9.85	2.288
6.15	1.816	7.40	2.002	8.65	2.158	9.90	2.293
6.20	1.824	7.45	2.008	8.70	2.163	9.95	2.298
6.25	1.833	7.50	2.015	8.75	2.169	10.00	2.303
6.30	1.840	7.55	2.022	8.80	2.175	10.25	2.327
6.35	1.848	7.60	2.028	8.85	2.180	10.50	2.351
6.40	1.856	7.65	2.035	8.90	2.186	10.75	2.375
6.45	1.864	7.70	2.041	8.95	2.192	11.00	2.397
6.50	1.872	7.75	2.048	9.00	2.197	12.00	2.485
6.55	1.879	7.80	2.054	9.05	2.203	13.00	2.563
6.60	1.887	7.85	2.061	9.10	2.208	14.00	2.639
6.65	1.895	7.90	2.067	9.15	2.214	15.00	2.710
6.70	1.902	7.95	2.073	9.20	2.219	16.00	2.775
6.75	1.909	8.00	2.079	9.25	2.225	17.00	2.833
6.80	1.917	8.05	2.086	9.30	2.231	18.00	2.890
6.85	1.924	8.10	2.091	9.35	2.235	19.00	2.944
6.90	1.932	8.15	2.099	9.40	2.241	20.00	2.996
6.95	1.939	8.20	2.104	9.45	2.246	21.00	3.044
7.00	1.946	8.25	2.110	9.50	2.251	22.00	3.091
7.05	1.953	8.30	2.116	9.55	2.256	23.00	3.036
7.10	1.960	8.35	2.122	9.60	2.262	24.00	3.178
7.15	1.967	8.40	2.128	9.65	2.267	25.00	3.219
7.20	1.974	8.45	2.134	9.70	2.272	30.00	3.378

per cent of the piston stroke. When the steam is admitted to the cylinder for 80 per cent of the piston stroke, the increase of power resulting therefrom is by no means proportional to the increased expenditure of steam, as compared to the case when the steam is admitted to the cylinder for only 30 per cent of the piston stroke.

Less power is obtained from the engine when the steam is admitted to the cylinder for more than 80 per cent of the piston stroke, on account of the back pressure exerted by the steam against the piston on its return stroke. Not only is less power given by the engine, but it is obtained less economically as regards waste of fuel and steam. That point in the piston stroke at which the steam is no longer admitted to the cylinder by the valve is called the point of cut-off.

When the point of cut-off is at one-third of the piston stroke, the steam let into the cylinder during this time goes on expanding during the remaining two-thirds of the piston stroke and by its expansion does useful work. It also loses its high pressure and high temperature, and is discharged into the atmosphere after giving up a great deal of its heat energy.

If the cut-off be earlier than three-tenths of the piston stroke the advantage gained by expansion is counterbalanced by the fact that, if steam be admitted to the cylinder for a less portion of the stroke, it will, in expanding, cool the wall of the cylinder so much as to cause the fresh charge of steam during the next piston stroke to condense instead of expanding and doing useful work.

Therefore the point of cut-off, to have certain definite limits of economy, should be between three-tenths and eight-tenths of the piston stroke.

The exact value of the expansion portion of the piston stroke may be readily obtained by referring to a table of natural logarithms, for, when the curve is hyperbolic, the natural logarithm expresses the relation between the area during expansion and the area during admission.

If the steam is cut off at half stroke, it is expanded to twice its original volume, and if the area during admission $=1$, then the area during expansion $=$ the natural logarithm of 2, hence

the total area $=1+$nat. log. 2.

Now, on referring to Table No. 6, the natural logarithm of 2 is found to be .693, then

$$\text{the total area} = 1 + .693$$
$$= 1.693$$

and if R = the ratio of expansion, or the volume of the steam at the end of the stroke, divided by the volume at the point of cut-off,

then the area during expansion = nat. log. R,

and the total area $=1+$nat. log. R.

The following table gives the proportional values of the work done for various degrees of expansion.

TABLE NO. 7.—WORK DONE BY STEAM DURING ADMISSION AND EXPANSION.

Point of Cut off.	Ratio of expansion = R	Work done during Admission.	Work done during expansion = nat. log. R	Total work done.
Cut off at $\frac{3}{4}$ stroke	$1\frac{1}{3}$	1	0.262	1.262
Cut off at $\frac{1}{2}$ stroke	2	1	0.693	1.693
Cut off at $\frac{1}{3}$ stroke	3	1	1.098	2.098
Cut off at $\frac{1}{4}$ stroke	4	1	1.386	2.386
Cut off at $\frac{1}{5}$ stroke	5	1	1.609	2.609
Cut off at $\frac{1}{8}$ stroke	8	1	2.079	3.079
Cut off at $\frac{1}{9}$ stroke	9	1	2.197	3.197
Cut off at $\frac{1}{10}$ stroke	10	1	2.302	3.302

From this table it may be seen that, if the steam is cut off at one-third of the stroke, and expanded to the end, the work done is about twice that done by the steam during admission.

The exact proportion is 1 : 2.098.

If the steam had been admitted at its initial pressure throughout the whole stroke, three times the weight of steam would have been used, and the proportion of the work done in the two cases, supplying steam through the whole length of the stroke, or cutting off at one-third and expanding, would be as 3 to 2.098, in other words, to get half as much more work out of the engine, three times the weight of steam, and therefore also weight of fuel, will be consumed in the first case as compared with the second.

AVERAGE STEAM PRESSURE.

The average steam pressure on the piston in pounds per square inch is usually obtained from an indicator diagram, but it may also be found, if the initial steam pressure in the cylinder and the point of cut-off be known, by reference to Table No. 000.

Example: What is the average steam pressure in pounds per square inch, with an initial pressure of 120 pounds per square inch and the steam being cut off at one-third of the piston stroke?

Answer: Column 6 in Table No. 3, opposite 120 pounds, gives 83.9 as the average steam pressure in pounds per square inch, corresponding to a cut-off at one-third of the piston stroke. The average steam pressure on the piston in pounds per square inch may be also calculated from the following formula:

$$P=p\left(\frac{\text{Nat. Log. } R+1}{R}\right)$$

Where P is the average steam pressure required, p the initial pressure in the cylinder before the steam supply is cut off and R the ratio of expansion of the steam, which is equal to the whole length of the piston stroke divided by the distance the piston travels before the steam is cut off.

Example: What is the ratio of expansion with a piston stroke of 10 inches, when the steam supply is cut off after the piston has traveled three inches?

Answer: Ten inches divided by 3 inches equals 3⅓ as the required ratio of expansion.

Example: What is the mean pressure on the piston with the above ratio of expansion of 3⅓ and an initial pressure of 100 pounds?

Answer: From Table No. 6 the nearest number corresponding to 3⅓ is 3.35, the natural logarithm of which is 1.209, or, in round numbers 1.21. Then, by Formula No. 4 the mean pressure is

$$P=100\left(\frac{1.21+1}{3.33}\right)=66.34 \text{ pounds.}$$

The average steam pressure during the entire piston stroke should not be confounded with the mean pressure, which is the effective pressure of the steam during the expansion part of the piston stroke only, and is only used in connection with the calculation of the horsepower of compound and triple or quadruple expansion steam engines.

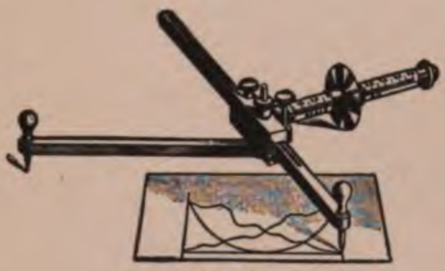


Fig. 90.

PLANIMETER.

The usual method of ascertaining the average pressure on the piston from an indicator card or diagram, is by means of a planimeter, Fig. 90, which is used to calculate the area of any irregular plane surface, by moving a tracing point attached to the instrument over the irregular boundary line of the figure.

In many cases it is found to be sufficiently accurate to calculate the average pressure by means of ordinates or vertical measurement lines, drawn upon the indicator diagram.

EXPANSION OF STEAM.

If advantage be taken of the expansive properties of steam then with steam at 100 pounds absolute pressure, expanded down to 15 pounds without back pressure, a very considerable increase is made in the work done.

For the steam is expanded 6.66 times, and the useful work is therefore $1+\text{natural log. } 6.66 = 1+1.896 = 2.896$.

That is, if the work done by 1 pound of steam at 15 pounds pressure equals 1, then by using the same weight of steam at 100 pounds pressure and expanding it down to 15 pounds without back pressure, nearly three times the amount of work is done per pound of steam used, and also per pound of fuel consumed, for the consumption of fuel depends upon the weight of steam used, and is nearly independent of the pressure of the steam, owing to the fact that the total heat in steam at high pressures is only a very little greater than the total heat in steam of lower pressures.

BACK PRESSURE.

Back pressure has a considerable influence on the total work done by a given weight of steam.

If the piston of a steam engine to be acted upon on one side by steam of 45 pounds absolute pressure, and if it be possible let there be no pressure acting on the other side of the piston. Then, if the pressure of the steam were maintained uniform throughout the stroke, the diagram of pressure and volume would be a simple rectangle.

But in non-conducting engines, when the steam acts on one side of the piston, communication is open with the atmosphere by means of the exhaust port on the other side, and it is, therefore, exposed to a back pressure of 14.7 pounds per square inch. The effective pressure is therefore 45—14.7=30.3 pounds per square inch, and the effect on the diagram is to remove all the lower part from zero to 14.7 pounds, and thus reduce the area of the figure, and therefore also the effective work done. In practice there is always an additional back pressure of 3 to 5 pounds, due to the incompleteness of the exhaust, making a total back pressure of about 18 to 20 pounds per square inch. It may be much more than this with higher piston speeds. If the cylinder were placed during the exhaust into communication with a condenser, then a large portion of the atmospheric pressure would be removed, and a back pressure of not more than about 3 pounds absolute would oppose the motion of the piston. In this case the area of the figure representing the effective work done would be extended to within about 3 pounds of the vacuum line, the gain of work being proportional to the gain of area, while the weight of steam used in each case is clearly the same.

The effective pressure on the piston therefore equals the difference between the pressures on each side of the piston.

AVERAGE EFFECTIVE PRESSURE.

To find the average effective pressure of steam per square inch on the piston, by measurement from the indicator diagram, when a planimeter is not at hand:

Divide the line of volumes into eight or ten equal parts.

Measure the height of the diagram at each division by the scale of pressures.

Add these measurements together, and divide the sum by the number of measurements. The result will give the mean average effective pressure [illegible] square inch on the piston.

To find the total average pressu [illegible] iston, multiply the average pressure per sq [illegible] y the area of the piston in square inches.

The practical limit of the expansion of steam varies for different types and conditions of engines, and is the point, beyond which no further reduction in weight of steam consumed, per unit of power, can be obtained economically. The gain by further expansion beyond this point is more than neutralized by the loss from condensation in the cylinder, and from negative work done by the back pressure upon the piston.

It would therefore be useless to expand the steam to a pressure below that of the pressure at the other side of the piston.

Let steam at 44.1 pounds per square inch, or 58.8 pounds per square inch absolute pressure be admitted to the cylinder, and cut off at one-fourth of the stroke of the piston.

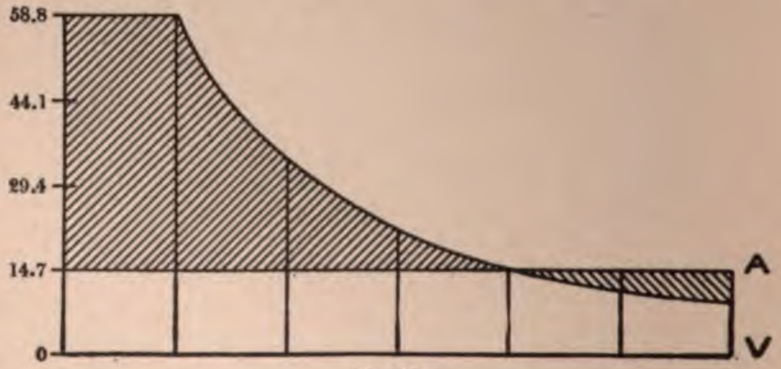


Fig. 91.

IDEAL INDICATOR DIAGRAM.

The theoretical useful work done by the expanding steam, is shown in Fig. 91, by the shaded portion of the diagram, from the commencement of the piston stroke to the intersection of the expansion curve by the atmospheric pressure line A. The negative or lost work which would be done if the degree of expansion were carried further, is shown by the shaded portion to the right in the diagram and below the atmospheric pressure line A. The pressure of the steam and the back pressure will therefore be equal, and any further extension of the expansion would be useless. In practice the expansion should not be carried as far as this. If the expansion be continued beyond four, to five or six expansions, the work done by the atmosphere against the piston towards the end of the stroke is greater than that done on it by the steam. The steam should never be cut off so early as to cause it to expand to a pressure below that of the back or atmospheric pressure acting against the piston.

As the theoretical limit of the number of the expansions $= \frac{\text{initial pressure}}{\text{back pressure}}$. In the above example the $\frac{\text{initial pressure}}{\text{back pressure}} = \frac{58.8}{14.7} = 4$ expansions. In good practice the maximum number of expansions should not exceed three-fourths of the theoretical limit.

CONDENSATION OF STEAM.

If steam be admitted to the cylinder of an engine which is cooler than the entering steam, the steam gives up some of its heat to the cylinder walls, a portion of the steam is condensed and deposited on their surface, and more steam consequently enters the cylinder to take its place, while the temperature of the cylinder walls rises to that of the steam in contact with them.

If the steam were supplied the cylinder at its initial pressure and temperature throughout the whole piston stroke, and the exhaust port be then opened, the steam would escape into the air, and the pressure in the cylinder fall to that of the atmosphere, or nearly so.

But the water which has been formed, being in contact with the walls of the cylinder at the tem [illegible] ture of the initial steam, will evaporate immediate [illegible] sure is reduced by the opening of the exh [illegible] become reconverted into steam at the e [illegible] heat in the walls of the cylinder, thereby cooling them to the temperature of the steam during the exhaust stroke.

The steam thus re-evaporated during the exhaust stroke not only absorbs heat from the cylinder walls, which will have to be made up from the entering steam during the next stroke, but passes away to the air without doing any useful work.

When the piston reaches the end of its stroke, fresh steam is admitted into the cylinder and comes in contact with the cooled surface of the cylinder cover, piston, and steam ports, which have been exposed to the lower temperature of the exhaust steam, and the same process of condensation and re-evaporation is repeated.

Condensation, consequently takes place during the early part of the piston stroke, while re-evaporation occurs partly towards the end of the stroke and partly during the exhaust stroke. The re-evaporation during the expansion behind the piston helps the piston, and increases the total work done, but the steam re-evaporated during the exhaust stroke in a single-cylinder engine is wasted. The loss due to the condensation of steam in the cylinders of all steam engines varies from 10 to 30 per cent, or more, of the steam consumed, the loss becoming greater as the mean temperature of the cylinder walls becomes less than the temperature of the initial steam.

Condensation increases as the degree of expansion in the cylinder increases, because there is a decreasing temperature of the walls with a constant initial temperature of the steam.

The advantage of using high-pressure steam is due to the property it possesses of doing work by expanding behind the piston after the supply of steam is cut off from the cylinder.

There is a limit to the useful expansion of steam in a single cylinder, owing to the excessive condensation in the cylinder with a high degree of expansion, resulting in increased consumption of fuel instead of a saving.

The secret of economy is to supply the cylinder with dry steam, and to maintain it as dry as possible throughout the stroke.

The laws which govern the condensation of steam in the cylinder are not at present fully understood. The means adopted to reduce the amount of water of condensation in the cylinder are:

Having the steam come from the boiler as dry as possible, and maintaining it in the dry condition by carefully covering the pipes traversed by the steam, on its way to the engine with non-conducting material.

Placing a water-separator in the steam-pipe just before entering the engine.

Jacketing the cylinder with hot steam. The addition of the steam jacket reduces the amount of condensation in the cylinder. The jacket is the more necessary the greater the degree of expansion in one cylinder, and the slower the piston speed.

Compression of a portion of the exhaust steam by closing the exhaust port before the end of the piston stroke, and allowing the piston to compress the steam and thereby to raise its pressure and temperature, and also the temperature of the cylinder cover, steam port and piston, before the new steam is admitted.

Increasing the piston speed of the engine.

Superheating the steam, that is, applying additional heat to the steam on its way from the boiler to the engine.

CYLINDER CLEARANCE.

The piston in a cylinder when at the end of its stroke should not touch the end or cover of the cylinder, but there should be a certain amount of space left between the piston and cover to prevent their coming into actual contact. In addition to this space, there is the port between the face of the slide valve and the cylinder, by which the steam is conducted to the cylinder. These two spaces, shown at c in Fig. 92, which make up the whole space between the face of the valve and the face of the piston when the piston is at the end of its stroke, are called the clearance.

Let the volume displaced by the piston during its stroke equal 9 cubic feet, and the volume of the clearance equal 1 cubic foot. When steam is admitted to the cylinder 1 cubic foot is used to fill the clearance space before the piston moves and if steam were used at full pressure throughout the piston stroke, 9 cubic feet more would be required to displace the piston. Thus 10 cubic feet of steam passes through the engine without doing any work, representing a loss of 10 per cent.

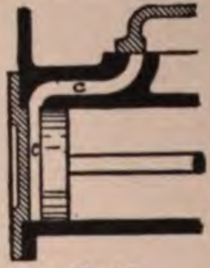


Fig. 92.

But suppose the steam is cut off at one-ninth of the stroke. During admission there is required 1 cubic foot of steam to fill the clearance, and which at first does not work on the piston, then another cubic foot to displace the piston when the steam is cut off. There are now 2 cubic feet of steam at initial pressure enclosed in the cylinder. Expansion commences, and at the end of the stroke the volume occupied by the steam will evidently be 10 cubic feet. The pressure of the steam at the end of the stroke is therefore one-fifth of the initial pressure.

If there had been no clearance then there would have been 1 cubic foot of steam in the cylinder at point of cut-off, which would expand to 9 cubic feet with a terminal pressure of one-ninth of the initial pressure.

Suppose the initial pressure had been 180 pounds absolute pressure. Then, neglecting the effect of clearance, the terminal pressure would be $\frac{180}{9}=20$ pounds per square inch absolute pressure.

Including the clearance, the terminal pressure would be $\frac{180}{5}=36$ pounds per square inch absolute pressure, or nearly twice the terminal pressure obtained when the clearance is neglected.

LAP AND LEAD OF SLIDE VALVES.

When a valve has no lap, it will move on each side of its central position, in order to open the steam port fully, a distance equal to the width of the port, and would deliver steam to the cylinder the entire length of the piston stroke were not some means employed to prevent this happening. But, when lap is added to the valve, the distance moved on each side of its central position must be increased, if the port is to be fully opened, to the width of the port plus the lap.

This advantage is overcome in two ways: By adding *lap* to the valve, that is, by extending the width of its face, and by giving it *lead*, that is, by causing it to move forward so as to open the port just before the piston reaches the end of its stroke. The amount by which the valve overlaps the edges of the steam port when at the middle of its stroke is called the *lap* of the valve.

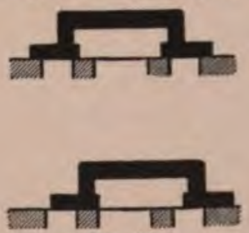


Fig. 93.

The amount by which it overlaps the outside edges is called the *outside lap*.

The amount by which it overlaps the inside edges is called the *inside lap*.

The upper view in Fig. 93 shows a slide valve with both inside and outside lap.

The amount of opening of the port for the admission of steam when the piston is at the beginning of its stroke is called the *lead* of the valve. The opening shown in the lower view in Fig. 93 is the lead of the valve, and the piston at this moment is at the beginning of its stroke.

The inside lap being less than the outside lap, the lead to the exhaust port is greater than that to the steam port, which permits of a ready escape of the exhaust steam.

The effect of the addition of *outside lap* is:

To cut off the steam at some earlier point of the stroke.

To require the eccentric to be moved forward on the shaft, which results also in an earlier opening of the exhaust port.

The effect of the addition of *inside lap* is:

To close the exhaust port at an earlier point in the stroke, producing compression of the steam at the back of the piston.

To delay the opening of the exhaust port.

HORSEPOWER OF GASOLINE MOTORS.

A horsepower is the rate of work or energy expended in raising a weight of 550 pounds one foot in one second, or raising 33,000 pounds one foot in one minute. This is far more work than the average horse can do for any great length of time. A good horse for a short period of time can do much more.

As the ordinary formula used for the calculation of horsepower in connection with steam engines is not directly applicable to explosive motor practice, formulas are here given that are more suited to the purpose.

Let D be the diameter of the cylinder in inches, and S the stroke of the piston also in inches; if N be the number of revolutions per minute of the motor, and H.P the required horsepower of the motor, then for a four-cycle motor

$$H.P.=\frac{D^2\times S\times N}{18,000}$$

Example: What horsepower should be developed by a motor of 4½ inches bore and stroke, at a speed of 1,200 revolutions per minute?

Answer: As the bore and stroke of the motor are alike, the square of the bore multiplied by the stroke is equal to the cube of 4½, which is 91.125, this multiplied by 1,200, and divided by 18,000, gives 6.08 as the horsepower of the motor.

From a theoretical standpoint a two-cycle explosive motor should not only have as great a speed but also be capable of developing almost twice the power that a four-cycle motor does. It is a fact nevertheless that its actual performance is far different.

The horsepower of a two-cycle motor may be calculated from the following formula,

$$H.P.=\frac{D^2\times S\times N}{21,000}$$

Example: Required, the horsepower of a two-cycle motor of 4½ inches bore and stroke, with a speed of 900 revolutions per minute?

Answer: The square of the bore multiplied by the stroke is equal to 91.125, which multiplied by 900, and divided by 21,000, gives 3.91 as the required horsepower. The results given by the above examples agree very closely with those obtained from actual practice.

THE INDICATOR.

The thermal or heat efficiency of an explosive motor [illegible] be determined from an indicator diagram, which [illegible] a representation of the internal conditions through- [illegible] entire cycle of operations. The diagram tells [illegible] things essential to be known.

[illegible] the initial explosive pressure, or the pressure [illegible] after ignition has taken place. It shows [illegible] volume of the charge is diminished during [illegible] admission. [illegible] gives the point of ignition, when the ignition is complete and when expansion begins. It indicates the pressure of expansion during the working stroke. It gives the terminal pressure when the exhaust is opened. It shows the rapidity of the exhaust. It indicates the back-pressure on the piston, due to the exhaust. It shows the point of opening of the exhaust. It gives the mean power used in driving the engine. It also indicates any leakage of valves or piston.

The usual method of ascertaining the area of an indicator diagram is by means of an instrument known as a planimeter, which is used to calculate the area of any irregular surface, by moving a tracing point attached to the instrument over the entire irregular boundary line of the figure.

But for the purpose of ascertaining the horse-power of an engine it will be sufficiently accurate to illustrate the principles involved, to calculate the area of the diagram by means of ordinates or vertical measurements.

The upper drawing in Fig. 94 represents a card taken from an engine of 4 inches bore and 6 inches stroke, with a speed of 900 revolutions per minute, and under a full load. The diagram is divided into 12 parts as shown by vertical lines, the lengths of which are in terms of the spring, which is 100. Then 1.90+1.36+1.00, etc., divided by 12, equals 0.665 as the average height of the diagram. Its length is 6 inches, as shown, therefore the area of the card is approximately 3.99 square inches. As the initial explosive force from the diagram is 250 pounds per square inch, and a 100 indicator spring used, the height of the card is 250 divided by 100, which equals 2½ inches as the height of the card. The mean effective pressure on the piston in pounds per square inch will therefore be equal to the area of the diagram 3.99, divided by the area of the whole card, which is 2½×6, equals 15, and multiplied by 250, the initial explosive force, or 3.99×250, and divided by 15, equals 66.5 pounds per square inch as the mean effective pressure required.

From this the indicated horsepower of the engine can readily be found as follows:

Let M.P be the mean effective pressure in pounds per square inch, A the area of the cylinder in square inches, S the stroke of the piston in inches, N the number of explosions per minute, and H.P the indicated horsepower, then

$$H.P = \frac{M.P \times A \times S \times N}{396{,}000}$$

$$= \frac{66.5 \times 12.56 \times 6 \times 450}{396{,}000} = 5.69$$

as the required indicated horsepower of the engine. The indicated horsepower of any engine will always be greater than that obtained from a brake test, as it simply represents the actual thermo-dynamic (heat-pressure) conditions within the cylinder, and takes no account of friction and other external losses.

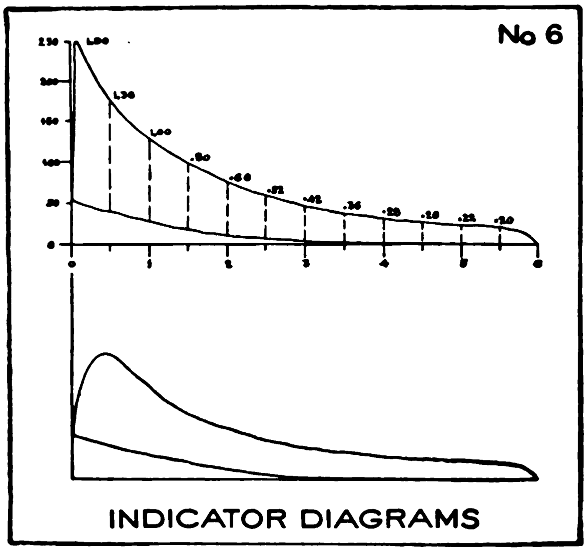


Fig. 94.

The lower drawing in Fig. 94 is a card taken from the same engine running under half load.

An indicator consists of a cylinder within which works a piston under the tension of a helical spring of predetermined strength. The rod attached to the piston carries a pivoted arm which works on a horizontal lever. This lever carries a pencil bearing against a drum. This drum is so arranged with a spring that it may be partially rotated by the pull on an attached string. A sheet of paper is wound on the drum and held in place by spring clips. The pressure in the cylinder acting on the spring causes the pencil to mark the paper, the indicator card or diagram being traced by the forward and backward movement of the drum.

The most suitable indicator for explosive motors is the McInnes-Dobie. It is fitted with a device which takes a continuous record by means of a rotating drum. Another device is the mirror-indicator of Hospitalier.

PRONY BRAKE.

There is only one way by which the actual horsepower of an engine may be correctly ascertained and that is by the use of the Prony brake, so called after its inventor. This simple device gives the actual energy in foot-pounds per minute delivered by the engine at its driving shaft.

The apparatus for making a brake test is fully illustrated in Figure 95. Two brake-blocks A partially surround the pulley P and are attached to the clamping pieces B and C, which hold the brake-blocks upon the pulley by means of the bolts D, springs E and thumb-nuts F. The lever G is double-ended for the dual purpose of balancing itself and also supplying a place of attachment for the weight W to balance the weight of the spring scale S.

In using this form of Prony brake, the engine is started in the direction indicated by the arrow on [illegible] drawing, the brake-blocks A are then tightened by [illegible] of the springs E and thumb-nuts F. Then the [illegible] of the spring scale S and the speed of the pulley P [illegible] taken.

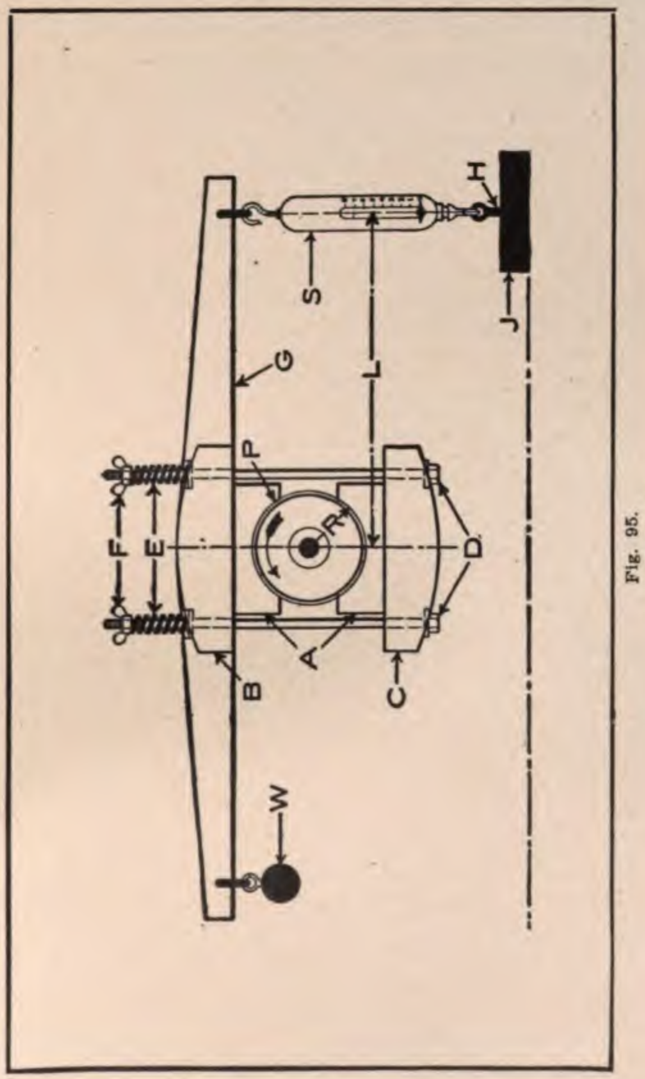


Fig. 95.
PROSY BRAKE.

The engine should be tested at varying speeds and the pull on the spring scale S noted for each.

The actual horsepower can then be calculated for each test and what is known as the critical speed of the engine determined, that is the speed at which the engine develops the greatest brake horsepower.

The following formula gives the actual horsepower obtained from the results of a Prony brake test: Let L be the length of the scale lever in inches, and S the pull indicated by the spring scale in pounds. If N be the number of revolutions per minute of the pulley R and B.H.P. the actual or brake horsepower of the engine then

$$\text{B.H.P.} = \frac{L \times S \times N}{63{,}025}$$

Example: An engine of 5 inches bore and stroke at 600 revolutions per minute gives a pull at the spring scale of 32 pounds, the scale lever is 24 inches long. What is the brake horsepower of the motor?

Answer: Twenty-four inches multiplied by 32 and by 600 equals 460,800—this divided by 63,025 gives 7.30 as the brake horsepower of the engine.

The weight J is shown for use in case the floor of the testing room should be of brick or cement; if of wood the eye-bolt H can be screwed directly into the floor.

CHAPTER XXVI.

IGNITION MECHANISM.

COMMUTATORS.

Commutators with a make and break form of contact-maker, should have the platinum contacts cleaned at least once a week, with a small piece of fine sandpaper or emery cloth.

Commutators having a rotary wiping form of contact, should have the brass or copper segment thoroughly cleaned in the manner just described, and all grease or dirt removed from the fiber portion of the commutator.

All thumb or lock-nuts and adjusting screws should be carefully gone over, and the condition of the wiring from the battery and coils examined very closely. Ten minutes spent in this manner once a week may save long delays and much laborious work at some future time.

Some forms of high speed gasoline motors with an induction coil of the single-jump-spark type, have a device known as a contact-breaker to open or break the electric circuit of the battery and coil, at the proper time for the passage of the arc or spark at the points of the spark plug. On account of the extremely high speed of such motors, and to allow time for the magnetism or magnetic flux in the core of the coil to attain a density sufficient to produce a good spark at the plug points, it is found necessary to keep the battery and coil in a closed circuit, except during the brief interval necessary for the passage of the spark at the plug points.

Figure 96 illustrates one form of contact-breaker. The left-hand end of the double lever is kept in contact with the lower end of the insulated pin, by means of a short spring immediately below it. When the nose of the cam engages with the roller in the fork or jaw at the right-hand end of the double lever, instant separation of the nose of the insulated pin and the left-hand end of the double lever takes place, breaking the electric circuit and causing a spark to occur at the points of the spark plug.

The electric circuit of the battery and coil is completed by one wire being connected with the lock-nuts on the upper end of the insulated pin and the other wire grounded on the case of the contact-breaker.

One of the simplest methods of electric ignition for explosive motor use is that known as the single-jump-spark system, with which a plain induction coil without a vibrator or trembler is used. The secondary spark is produced by means of a mechanical device operated by the cam shaft of the motor. The devices illustrated and which are known as contact-makers, cause a spark to arc or jump between the points of the spark plug in the combustion chamber of the motor.

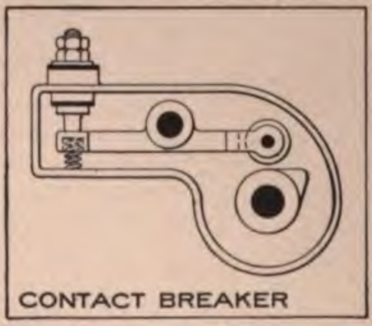


Fig. 96.

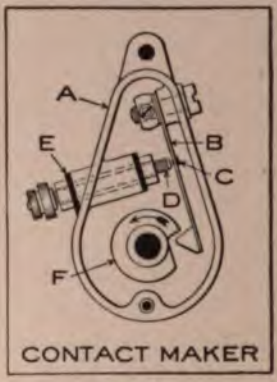


Fig. 97.

Figure 97 shows one form of contact-maker. The case A is usually attached to the gear box of the motor. Attached to a boss on the inside and near the upper end of the case is the trembler B, consisting of a flat steel spring with a nose at its lower end. Near the center of the spring is a platinum contact-point C. On the opposite side of the case is a bushing with insulation E, carrying the screw D, which is so adjusted that it does not quite contact with the platinum point C of the trembler. As the cam F revolves in the direction indicated by the arrow, it comes in contact with the nose of the trembler B, and pushes the platinum point C still further away from the screw D. Shortly before the cam has arrived at the position shown in the drawing, it has released the nose of the trembler, allowing it to fall, this action produces a vibrating effect, opening and closing the circuit repeatedly and with great rapidity, between the point C and screw D.

This is supposed to cause a stream or succession of sparks to occur between the plug points in the combustion chamber of the motor. In practice, however, and at a high rate of speed, only a single spark occurs.

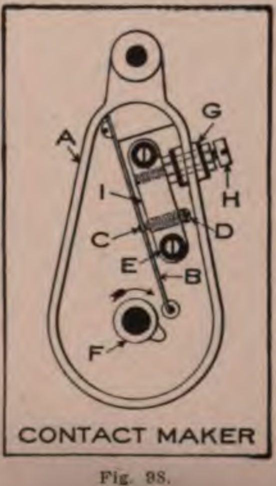


Fig. 98.

Another form of contact-maker is shown in Figure 98. The trembler B has a small roller upon its lower end which at the proper time is engaged by the [illegible] of the cam F. The screw D is carried in a [illegible]

I, which is attached to the back of the case A by suitable insulating bushings E. The screw H in the insulated bushing at G, makes the electrical connection from the coil and battery, through the block I and screw D, to the platinum contact C on the trembler B. The operation of this device is precisely the same as that of the one shown in Figure 98.

The commutator of the ignition system of a multi-cylinder gasoline motor has a three-fold use: To switch the battery current in and out of the electrical circuit at the proper time—To transfer the battery current successively from one coil to another— To vary the point or time of ignition of the explosive charge in the motor cylinder.

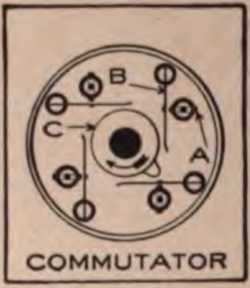


Fig. 99.

The commutator shown in Figure 99 is for a four-cylinder motor and is designed for use with induction coils without vibrators, which are known as single-jump spark coils. The studs of the screws A and the springs B are carried by insulated bushings located in the back of the commutator case. The nose of the cam C successively engages with the springs, causing them in turn to make contact with their respective screws. The battery and coil circuit is completed through the screws A, and a ground to the cam C, by means of the springs B, when in contact with their respective screws and the cam.

This device is said to cause a good spark at the plug on account of the quick break between the spring and the screw, the electrical circuit being broken the instant the spring leaves the screw and before the cam has allowed the spring to resume its normal position. This form of commutator cannot be short-circuited by oil or dirt getting between the spring and the screw, as the spring B only forms a part of the electrical circuit when in contact with both the cam C and the screw A.

Another form of commutator for a four-cylinder motor is illustrated in Figure 100, which has a rotary spring contact-maker A, which engages successively

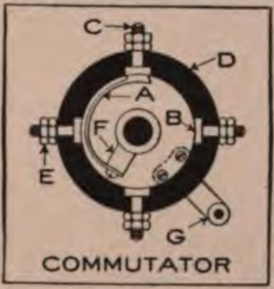


Fig. 100.

with the heads B of the screws C. The screws are spaced equidistant around the fiber ring D, which also forms the case of the commutator and are held in posi- by the lock-nuts E. The spring contact-maker A is attached to a hub F on the cam shaft of the motor. The time or point of ignition may be varied by moving the commutator case about its axis by means of a rod attached to the arm G.

Figure 101 shows two commutators of very similar construction. The one at the left in the drawing is for a two-cylinder motor and has flat spring-steel contact-makers. The commutator shown at the right of the drawing is for a four-cylinder motor and instead of having flat spring contact-makers, it has either carbon or copper contact-brushes, which are held against the commutator by short coil springs in the insulated bushings located around the periphery of the commutator case. The commutator is made of vulcanized fiber with a short brass or copper segment, which is grounded to the cam shaft as shown.

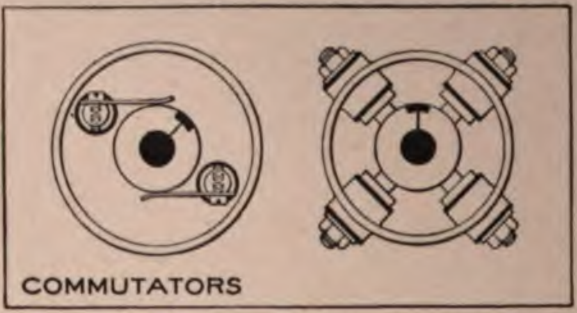


Fig. 101.

WIPING CONTACT COMMUTATORS.

The forms of commutators illustrated in the drawings may be constructed for use with a motor of any number of cylinders, by increasing or decreasing the number of contact-makers located around the commutator.

IGNITION CIRCUITS.

Figure 102 illustrates the ignition circuit of a single cylinder motor, showing plainly the battery, coil and commutator connections. A reference table accompanies Diagram No. 3, giving the names of the various parts shown in the drawing of the ignition circuit.

Figure 103 shows a method of wiring for a single cylinder motor, using two sets of dry batteries, a storage battery and a set of dry batteries, or a set of dry batteries and a generator. By moving the switch finger, either the generator or the battery may be used as desired, or both cut out.

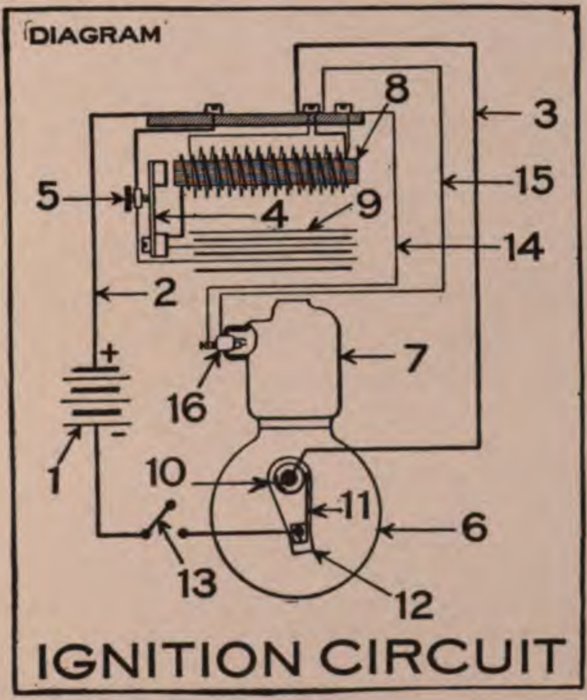


Fig. 102.

IGNITION CIRCUIT FOR SINGLE CYLINDER MOTOR.

1—Battery.
2 and 3—Primary wires.
4—Vibrator.
5—Contact screw.
6—Crank case.
7—Cylinder.
8—Induction coil.
9—Condenser.
10—Commutator.
11—Contact maker.
12—Commutator case.
13—Switch.
14 and 15—Secondary wires
16—Spark plug.

Multi-cylinder gasoline motors may have the wiring of their ignition circuits arranged in various manners, as follows:

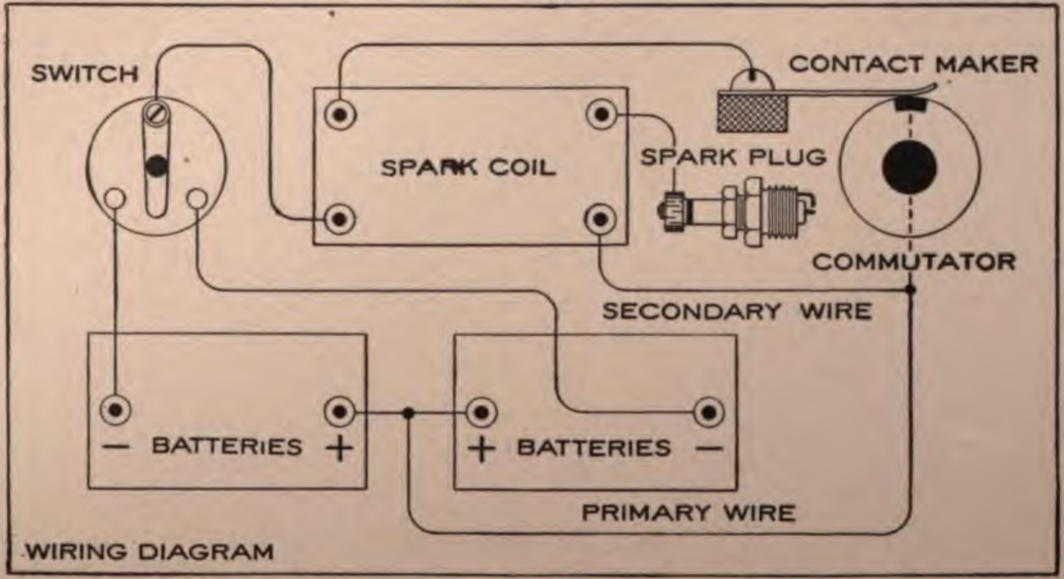


Fig. 103.

WIRING FOR SINGLE CYLINDER MOTOR.

Two-cylinder Motor. Single-coil, with the two spark plugs in series with each other. A four terminal coil is necessary to use with this arrangement.

Duplex-coil, with the two spark plugs independently connected to the secondary winding of the coil, one end of each secondary wire being grounded to the frame or motor.

Four-cylinder Motor. Two coils, with each pair of spark plugs in series with each other. Two four-terminal coils are necessary with this arrangement.

Four coils, with the four spark plugs independently connected to the secondary winding of the coil, one end of each secondary wire being grounded on the frame or motor.

The wiring for the ignition circuit of a four-cylinder motor is illustrated in Fig. 104. The commutator, quadruple-coil, spark plugs, and duplex battery system are plainly shown. For the wiring for the ignition circuit of single-cylinder motors see Fig. 103.

In a single-cylinder motor the complete breakage of a wire or the loosening of a connection, or the displacement of the wire leading to the spark plug will cause an instant stoppage of the motor. In a multi-cylinder motor such an accident will probably slow the car and cause one cylinder to miss, with the result probably of explosions in the muffler.

IGNITION TIMING.

It should be remembered that ignition timing is not the same thing as ignition governing, therefore to obtain the best results from an explosive motor the charge should be ignited at the best possible moment.

With too early ignition the presssure upon the piston becomes excessive and without any adequate return of useful work or energy. If the ignition be retarded too much, the maximum explosive pressure occurs too late during the working or power stroke of the piston and the combustion of the gases is not complete when the exhaust-valve opens. Greater motor speed requires an

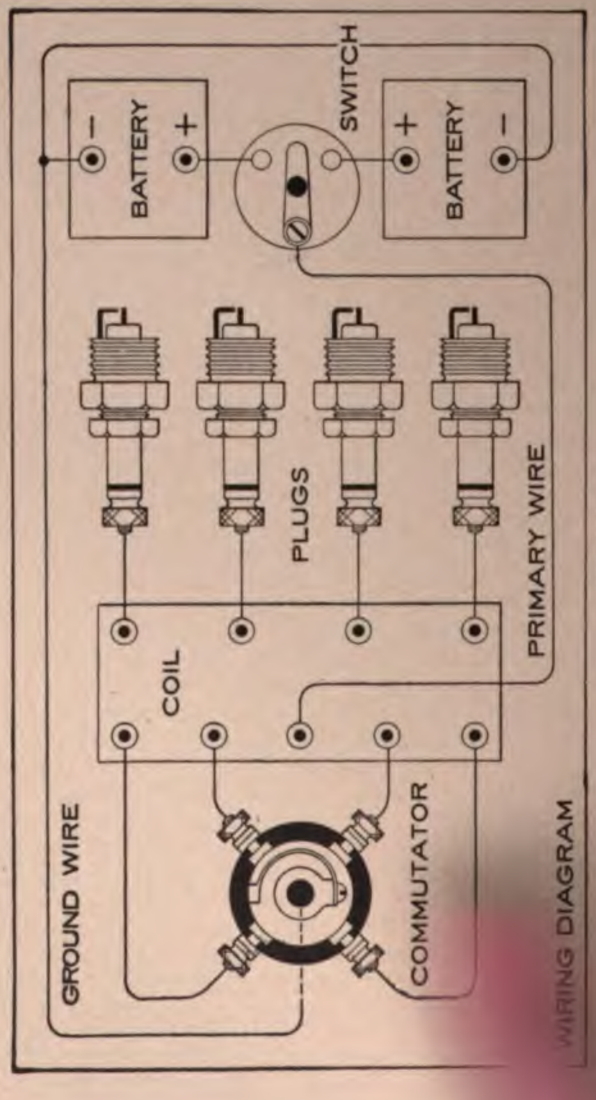


Fig. 104.
WIRING FOR FOUR CYLINDER MOTOR.

early ignition of the charge, but greater power calls for late or retarded ignition.

The reason for advancing the spark when fast running is required, is that the explosion or ignition of the charge is not instantaneous as may be supposed, but requires a brief interval of time for its completion.

When running a motor with the ignition retarded, the mixture should be throttled as much as possible, otherwise the motor will overheat.

Always retard the ignition before starting the motor, and take great care that the ignition is retarded and not by mistake advanced. Some cars are fitted with a device which prevents the starting crank being turned unless the spark is retarded. If it is not clear as to which way to move the ignition lever, to retard the ignition, move the commutator in the same direction as the camshaft rotates.

As soon as the motor slows a little when going uphill, retarding the spark enables more power to be obtained from the motor at the slow speed, that is to say, if the spark is not retarded the motor will go slower than if it is retarded. Do not retard the lever to the utmost under these conditions, on the contrary, retard the lever to such a point that the knocking (due to the wrong position) ceases.

Retarding the spark causes the maximum pressure of the explosion to occur at the best part of the stroke, or, rather, the mean pressure of the explosion stroke will be lower, if the best point of ignition by retarding is not found. This is a matter of some skill and practice.

To slow the motor, cut off as much mixture as the
rottle allows, then slow the motor still further by re-
ding the spark, but on no account retard the spark
en the throttle is full open (for the purpose of slow-
the motor), as the motor will merely discharge a
tity of flame at a white heat over the stem of the
lve, burning it, softening it, and making it

al ignition requires some outside

source of electric energy such as a generator or battery to produce a spark in the combustion chamber of the motor. A primary or secondary induction coil is necessary in connection with the source of electric energy to give a spark of sufficient intensity to properly ignite the compressed charge in the combustion chamber of the motor. This method of ignition provides a means of varying the motor speed throughout a great range of speeds by advancing and retarding the point of ignition, or time of igniting the explosive charge.

The incandescent tube system of ignition consists of a tube of metal or porcelain, one end of which is closed and the other screwed or fastened into the combustion chamber by suitable means.

The flame of a Bunsen burner is projected against the tube, rendering it incandesecnt, resulting in the firing of the compressed charge slightly before the end of the compression stroke. This form of ignition has not obtained in automobile practice for several reasons, some of which are here briefly stated. It causes misfiring of the charge on account of either burned or partially consumed gases filling the tube. Again, the tube may be clogged with dead or burned gases almost its entire dength, causing premature ignition of the fresh charge of gas in the tube on account of its being too close to the combustion chamber. An almost entire absence of speed regulation of the motor, as the gases require a certain degree of compression to insure proper ignition. Throttling of the charge to obtain a variation in the speed of the motor is therefore almost prohibitive or can only be used within very close limitations.

It may be well to explain without entering into theoretical details, that when a motor is running at normal speed, the ignition-device is so set that ignition takes place before the piston reaches the end of its stroke. The later the ignition takes place the slower the speed of the motor and consequently the less power it will develop. If, however, in starting the motor the ignition-device were set to operate before the piston reached the end of its stroke, backfiring would result, resulting in a reversal of the operation of the motor and possibly in injury to the operator.

IGNITION TROUBLES.

Trouble may occur from the cam or commutator not being properly adjusted. The contact-screw of the induction coil vibrator may be loose.

The vibrator or trembler of the coil may not be properly adjusted.

To adjust the vibrator, turn the motor crank until the contact is closed, throw in the switch and listen for a good clear buzz from the vibrator. Do not allow it to buzz slowly but fast, until it makes a singing sound like a bumble bee, then turn the crank several times and again listen for the buzz. Sometimes the vibrator will buzz, but it will not buzz when the motor is running fast and the motor misfires; this is probably due to the fact that the adjusting screw has made the tension of the spring too strong and when a quick contact is made it does not have time to vibrate properly. Experience is the only teacher for properly adjusting the vibration of an induction coil.

Many troubles arise from faulty or defective insulation.

A wire placed too close to an exhaust-pipe invariably fails after a time, owing to the insulation becoming burnt by the heat of the pipe.

A loose wire hanging against a sharp edge will invariably chafe through in course of time.

If the insulation of the coil breaks down it cannot be repaired on the road, it should be returned to the makers. A slight ticking is usually audible inside the coil when this occurs.

All wires where joined together should be carefully soldered, the joints bein[illegible]wards insulated with rubber or prepared tapes. [illegible] make a joint in the secondary wires. See that [illegible]nals are tightly screwed up. When connecting [illegible]ed wire, the insulation must be removed, so th[illegible] the bare wire is attached.

Wires sometimes become broken, and being loose make only a partial contact.

Battery terminals frequently become corroded, they should be covered with vaseline, and require periodical cleaning. See that all connections at the battery are clean and bright.

The porcelain of the spark plug may be cracked and the current jumping across the fracture. The points may be sooty and require cleaning. They may be touching and require separating, or they may be too far apart. The usual distance between the points is about one thirty-second of an inch, which is approximately the thickness of a heavy business card.

Clean all oil and dirt from the commutator. Most commutators are so placed as to give the maximum possible opportunity to collect oil and dirt. They should always be provided with a cover.

In course of time dry or storage batteries will become weak or discharged. Always carry an extra set.

Spanners, oil-cans, tire-pumps, etc., have been known to get on the top of the batteries, thereby connecting the terminals together and causing a short-circuit.

The platinum contacts of the coil may become corroded. They should be cleaned with a small piece of emery cloth or sandpaper.

The platinum points on the trembler may become loose. They should be riveted up with a small hammer.

It frequently happens that oil and dirt accumulate on the platinum contacts, which interrupt the free flow of the current. Care should be taken, therefore, that they are always perfectly clean.

RELATION OF SPARK TO MIXTURE.

The relation of the time of the spark to the mixture is best learned by experience, but most always the highest speed will be obtained when the throttle is fully open and the spark well advanced. It, however, happens on bad roads and hills that the best results are sometimes obtained by retarding the spark a little, leaving the throttle full open. With the throttle almost closed and the spark fully retarded, the motor will just run itself. Do not open the throttle suddenly, as the mixture will be more uniform if the throttle is opened gradually.

Do not advance the ignition until the motor is up to speed on throttle. Advancing the spark suddenly, or before speed is attained with the throttle will cause pounding. Always advance the spark after the throttle is full open.

ROAD TROUBLES.

Aside from tire troubles and accidents which may happen to a horse-drawn vehicle as well as a motor-car, any one of the following troubles may occur:

Motor misfires badly.
Motor overheats.
Motor almost stops and then starts.
One or more cylinders not firing.
Regular but unusual hissing.
Regular but unusual knocking or pounding.
Regular but unusual puffing noise.

MOTOR MISFIRES BADLY.

With a single-cylinder motor this may be due to the fact that the points of the spark plug are too far apart, or that oil or soot has got on them. Misfiring in a multi-cylinder motor is caused from weak or exhausted batteries, a loose or broken wire in the ignition circuit, or a poor contact at the commutator. This applies also to a single-cylinder motor.

A failure in the water circulation from lack of water in the tank or an obstruction in the pipes is one cause of overheating. An insufficient supply or shortage of lubricating oil is another. Too rich a mixture or too much gasoline for the quantity of air also causes overheating, especially by running slow under a heavy load.

The gasoline tank may be almost empty or the cock in the supply pipe partially closed. The gasoline may be of low grade or stale. There may be dirt in the gasoline which has partially clogged the pipe leading to the carbureter. The union or flanged connection between the carbureter and the admission-pipe may be loose, allowing air to enter, thus preventing proper carburation of the mixture.

The points of the spark plugs may be too far apart, if not they may be short-circuited by oil or soot. If the motor has individual lubrication for each cylinder, too much oil may be feeding, defiling the mixture and preventing ignition of the charge. Stop the working of the vibrators of the coils, one at a time. In this manner the cylinder which is not firing may be quickly located.

A leak in the compression. Fill an oil can with soapy water and apply round the spark plug opening and the inlet or exhaust-valve chambers. Air bubbles will indicate the location of the leak. If the starting-crank be turned quickly the hissing noise will sometimes locate the leak.

Knocking is sometimes an indication that a piston or a bearing on the motor is about to seize through overheating. Advancing the ignition too far will produce the above result. A broken valve-stem, valve-spring, or a loose or worn wrist or crank-pin bearing will also cause a knocking or pounding.

If a puffing noise is heard which keeps time with the exhaust of the motor, but does not in any way affect the running of the motor, the connection between the motor and the main exhaust-pipe has worked loose, or there is a crack in the pipe. If the main exhaust-pipe is all right, one of the branch exhaust connections to the motor may be loose.

CHAPTER XXVII.

LUBRICATION AND LUBRICATORS.

To ensure easy running and reduce the element of friction to a minimum it is absolutely necessary that all such parts should be supplied with oil or lubricating grease, but it is also a fact, not so well understood, that different kinds of lubricant are necessary to the different parts or mechanisms of a motor-car.

As the cylinder of an explosive motor operates under a far higher temperature than is possible in a steam engine, consequently the oil intended for use in the motor cylinders must be of such quality that the point at which it will burn or carbonize from heat is as high as possible.

While a number of animal and vegetable oils have a flashing point, and yield a fire test sufficiently high to come within the above requirements, they all contain acids or substances which have a harmful effect on the metal surfaces it is intended to lubricate.

The general qualities essential in a lubricating oil for use in motor cylinders include a flashing point of not less than 360 degrees Fahrenheit, and fire test of at least 420 degrees, together with a specific gravity of 25.8.

At 350 to 400 degrees Fahrenheit, lubricating oils are as fluid as kerosene, therefore the adjustment of the feed should be made when the lubricator and its contents are at their normal heat, which depends on its location in the car. Steam engine oils are unsuitable for the dry heat of motor cylinders in which they are decomposed whilst the tar is deposited.

All oils will carbonize at 500 to 600 degrees Fahrenheit, but graphite is not affected by over 2,000 degrees Fahrenheit, which is the approximate temperature of the burning gases in an explosive motor. T [illegible]der of these motors may attain an average temperature of 300 to 400 degrees Fahrenheit. So that graphite would be very useful if it could be introduced into the motor cylinder without danger of clogging the valves and could be fed uniformly. These difficulties have not yet been overcome. Graphite is chiefly useful for plain-bearings and chains.

The film of oil between a shaft and its bearing is under a pressure corresponding to the load on the bearing, and is drawn in against that pressure by the shaft. It might not be thought possible that the velocity of the shaft and the adhesion of the oil to the shaft could produce a sufficient pressure to support a heavy load, but the fact may be verified by drilling a hole in the bearing and attaching a pressure gauge.

Roller and ball-bearings provide spaces, in which, if the oil used contains any element of an oxidizing or gumming nature, a deposit or an adhesive film forms upon the sides of the chamber, the rollers or balls, and the axle. This deposit will add to the friction, hence it is the more important to use a good oil or a petroleum jelly in such bearings.

Air-cooled motors, being hotter than water-cooled, must have a different lubricant, or one capable of withstanding higher temperatures.

The effect upon animal or vegetable oils of such heat would be to partially decompose the oils into stearic acids and oleic acid and the conversion of these into pitch. Such oils are therefore inadmissible for air-cooled motor use.

Mineral oils are not so readily decomposed by heat, but at their boiling points they are converted into gas, and any oil, the boiling point of which is in the neighborhood of the working temperature of the motor cylinder, is useless, as its body is too greatly reduced to leave an effective working film of oil between the cylinder and the motor piston.

The essentials for the proper lubrication of air-cooled motors are:

That the oil should not decompose.

That it should not volatilize, as this will result in carbon deposits.

That its viscosity should be equal to that of a good steam engine oil at similar temperatures.

That it should be fluid enough to permit of its easy introduction into the cylinder.

That it will have no corrosive effect on the cylinders and no tendency to gum.

That it will not oxidize with exposure to air and light.

Some makes of vertical cylinder motors use the splash system, whereby oil fed by gravity from a tank above the level of the crank-case flows into the crank-case, whence it is splashed over the piston and the wrist and crank-shaft bearings. The large end of the connecting-rod, which works in the crank-case, is made to dip or splash into a bath of oil. This lubricates the crank-pin. The splashing is invariably utilized to lubricate the cylinder by wetting the bottom of the piston and splashing into the cylinder. A little ring is sometimes made in the crank-case, into which the oil collects and into which also the end of the piston dips. The oil usually requires changing every 100 miles on small motors or every 75 miles on large.

With the use of high-speed gasoline motors, it has been found necessary to use a forced circulation of the oil in order to completely lubricate the interior of the cylinder. The usual method with high-powered motors is to employ a belt-driven pump to force the oil through adjustable conduits to the various moving parts. Such pumps, operating in ratio to the speed of the motor, supply lubricant more rapidly as the motor speed increases, and less as it decreases. Thus, a perfect supply is maintained, on the one hand, and flooding of the motor is prevented on the other.

Where horizontal cylinders are used, it is customary to use grease cups, and to control the feed by mechanical or spring pressure. Such devices are less [illegible]able for vertical cylinder motors, which require oil [illegible]rge quantities and exact adjustme[illegible] its flow. [illegible]y useful feature of oil pump lub[illegible]n is that [illegible] oil may be kept in proportion to the speed of the motor. This is a very necessary feature, as without it flooding is liable to result.

It should be ascertained from the maker of the car, how many drops of oil per minute are necessary for the different mechanisms of the car, including the motor. The lubricators should then be set accordingly.

It should be remembered that in cold weather when the oil is thick a different adjustment of the lubricators will be necessary from that found suitable in warm weather. It is important that the lubrication should be regular, and good oil used, but not too much. Too much oil will foul the spark plugs, clog the valves, and interfere with the quality of the explosive mixture. For this reason the lubricators should always be carefully closed when the car is stopped. If a mechanical lubricator is used, examine the mechanism sometimes, and do not trust entirely to the feed. If a pressure lubricator is used, see that the piston or cap is tight, for if not the pressure will stop the lubrication.

It sometimes happens that an oil pipe or oil hole is stopped up and needs cleaning, or perhaps the plug at the bottom of the crank chamber has come unscrewed and dropped out, losing all the oil. The proper amount of oil in the crank-case is about half a pint. An extra lubricator leading to the cylinders and crank-case should be fitted, so that extra oil can be fed by a hand pump, if there is any doubt about the motor getting enough.

Figure 105 shows four forms of lubricators for automobile use.

A—Plain, glass body oil cup, feeds only when shaft is running.

B—Sight feed, glass body oil cup, has an index-arm on top which indicates whether the oil feed is off or on.

C—Pressure feed, piston form of lubricator, for heavy bodied oil; the oil is forced into the bearings by means of a spring-actuated piston in the lubricator.

D—Plain grease cup, oil or grease forced into the bearing by screwing down the cap.

Smoke coming from the exhaust of a gas or oil engine is due to one of two conditions: Over-lubrication—too much lubricating oil being fed to the cylinder of the engine—or too rich a mixture, that is, too much gasoline and an insufficient supply of air.

The first condition may be readily detected by the smell of burned oil and a yellowish smoke. The second, by a dense white smoke accompanied by a pungent odor.

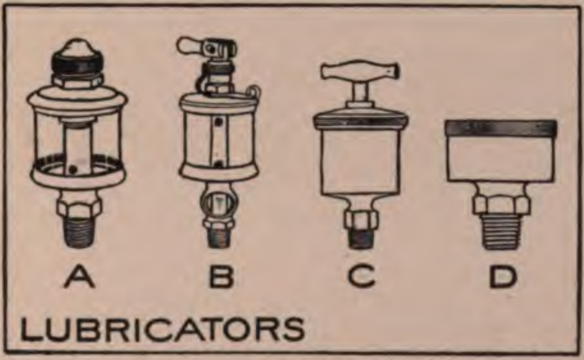


Fig. 105.

SIGHT AND COMPRESSION FEED LUBRICATORS.

If the engine is working properly, the exhaust should be almost colorless or with a light blue haze. The oil used should be of the highest flash-point obtainable, as the heat in a gas or oil engine cylinder is very dry and intense.

The effect upon animal or vegetable oils of such heat would be to partially decompose the oils into stearic acids and oleic acid and the conversion of these into pitch.

Mineral oils [illegible] so readily decomposed by heat, but at their boi[illegible]ts they are converted into gas, and any oil, the [illegible] point of which is in the neighborhood of the [illegible] temperature of the engine cylin[illegible] is useless, [illegible] is too greatly reduced to leave [illegible]ffective wo[illegible] on the cylinder walls.

CHAPTER XXVIII.

POWER TRANSMISSION DEVICES.

The power transmitting devices or mechanisms used on gasoline motor-cars may be divided into three classes: The differential gear which transmits the power from the speed-change-gear to the rear-axle or wheels of the car. The friction-clutch which forms the connecting and disconnecting medium between the motor and the speed-change-gear. The speed-change-gear which transmits the power of the motor to the differential gear at varying speeds, entirely independent of the motor speed.

Differential Gears. The differential gear of a motor-car acts in a similar manner to the whipple-tree of a two-horse wagon, the difference being that the differential gear acts continuously in a rotary manner, while the whipple-tree acts only through a short horizontal range of movement. It may also be compared with the equalizing bars of the locomotive driving wheels.

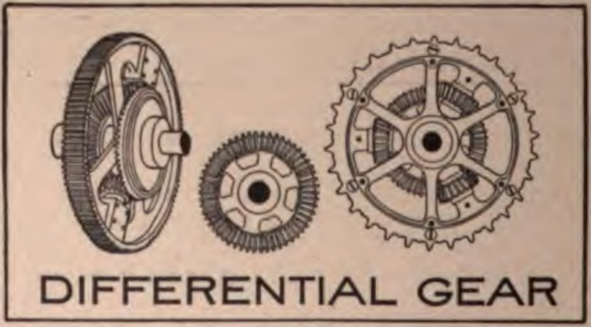


Fig. 106.

BEVEL GEAR FORMS OF DIFFERENTIAL GEAR.

Two forms of bevel gear differentials are shown in Figure 106. The one at the left of the drawing has a spur gear drive, and is much used on electric cars with motors directly attached to the rear-axle. The differential at the right of the drawing has a sprocket wheel instead of a gear, through which the gear is driven.

Figure 107 illustrates two spur gear differentials. The left-hand one having an internal tooth spur gear and fixed sprocket wheel, while the right-hand differential has all external tooth spur gears, and may be fitted with either a sprocket wheel or a spur gear form of drive.

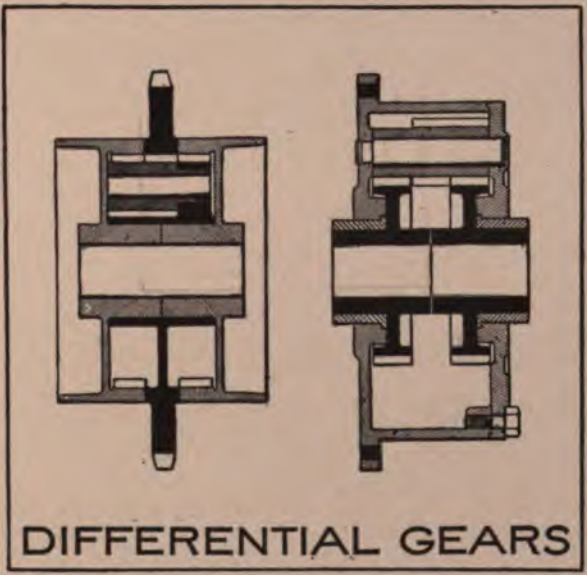


Fig. 107.
DIFFERENTIAL GEARS WITH EXTERNAL BRAKE BAND.

FRICTION-CLUTCHES. Friction-clutches are of various forms, amongst these may be mentioned those which are generally used on gasoline motor-cars; they are: The external band-clutch, the internal expanding-ring clutch, the disk or end-plate clutch and the cone-friction form of clutch. The female member of the cone-friction clutch is usually an integral part, or attached to the rim of the motor flywheel. A form of cone-friction clutch is shown in Figure 108, in which the female member is attached to the rim of the flywheel by bolts. The driving engagement is effected by the pressure of a spring located around the extension of the flywheel shaft, and between the hub of the flywheel and that of the male member of the clutch. Disengagement of the clutch members is made by foot pressure on a pedal attached to the bell-crank lever shown to the right in the drawing.

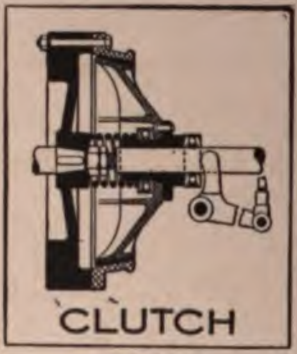


Fig. 108.

CONE FLY WHEEL FRICTION CLUTCH.

SPEED-CHANGE-GEARS. The gears which effect the change of speed of motor-cars, independently of that of the motor, are of many varieties, among which may be mentioned the following: Planetary-gears, Internal-gears, Internal-clutch gears, Sliding-gears and Positive-clutch gears.

A planetary or epicyclic form of speed-change-gear is illustrated in Figure 109, which has two speeds forward and a reverse. The fast speed is obtained by means of the disk or plate-friction clutch shown at the left in the drawing, which locks the parts of the gear together so that it revolves with the motor shaft as a single unit. When on the slow speed the reverse gears are in action, but at a slower rate of speed than the forward motion of the device.

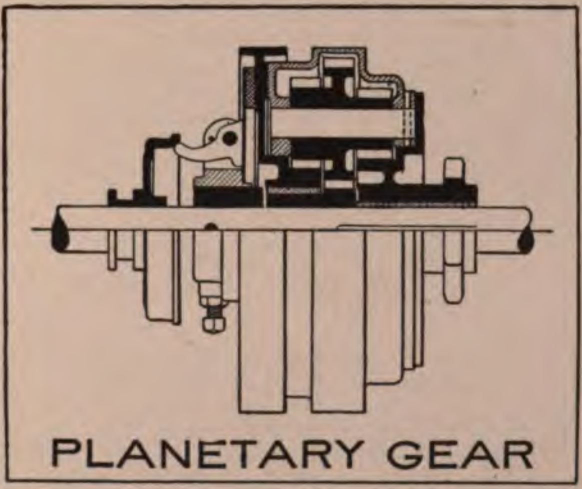


Fig. 109.

PLANETARY GEAR TRANSMISSION WITH FIBRE FRICTION CLUTCH.

Figure 110 shows a form of internal planetary speed-change-gear, also having two speeds forward and a reverse. The fast speed is obtained in the same manner as the gear described in Figure 109. When the gear is running on the slow forward speed, the internal gear of the reverse is running backwards at nearly the same rate of speed as the slow forward gear, a feature which has many objections.

A speed-change-gear having internal or individual clutches in each change-gear, is shown in Figure 111. These clutches are operated one at a time by means of the cones on the ends of the grooved collars, engaging with the dogs attached to the male members of the clutches. The reverse is obtained by means of an idler pinion shown between the two gears at the right in the drawing. Figures 112 and 113 show two forms of

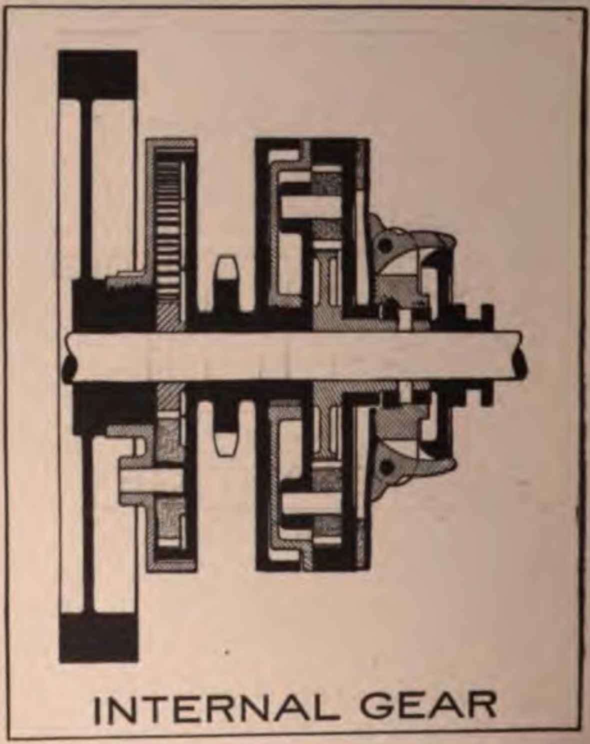


Fig. 110.

INTERNAL OR EPICYCLIC GEAR TRANSMISSION.

speed-change-gears with spur teeth which slide in and out of mesh with each other, hence the term, sliding-gear. The gear shown in Figure 112 has a device by

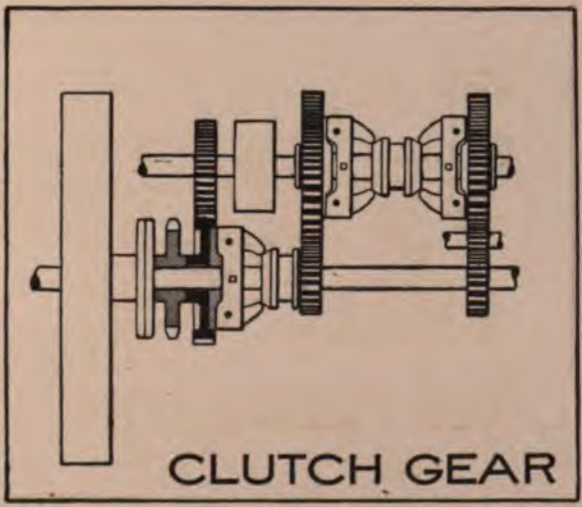


Fig. 111.
TRANSMISSION WITH INDIVIDUAL CLUTCHES.

which the cone-friction-clutch is thrown out of gear, before the various pairs or sets of gears are engaged or disengaged with each other. Both speed-change-gears have three speeds forward and a reverse.

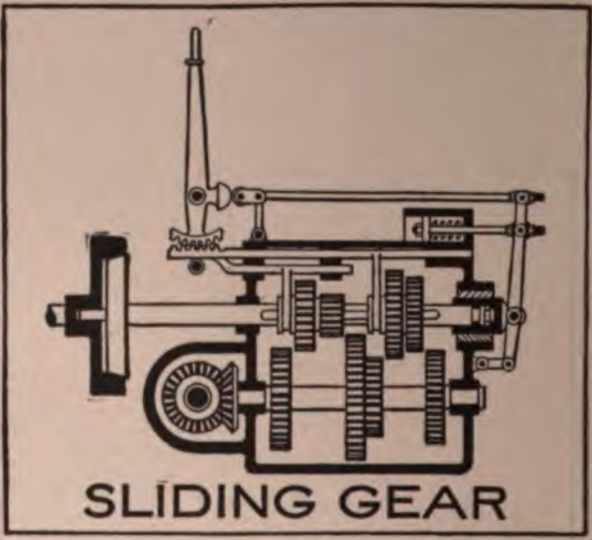


Fig. 112.

SLIDING GEAR TRANSMISSION WITH SPLINED SHAFT.

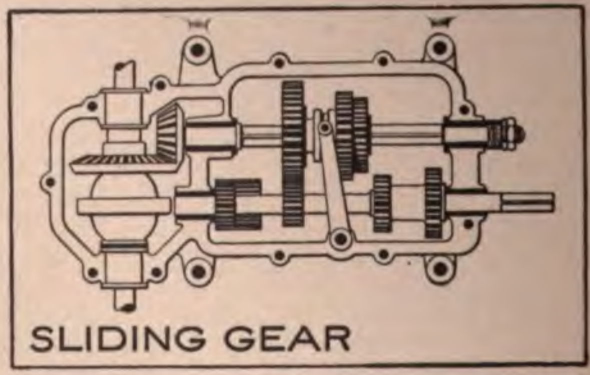


Fig. 113.

SLIDING GEAR TRANSMISSION WITH SQUARE SHAFT.

CHAPTER XXIX.

SPARK PLUGS.

SPARK GAPS.

An extra spark gap in the secondary circuit will cause a spark to jump across the points of a fouled plug because the intensity of the voltage of the current is reduced to such an extent that the current will jump across the points in preference to the path of higher resistance formed by the carbon deposit upon the insulation of the spark plug. As the spark plug and the spark gap are in series with each other, it follows that with a single gap—the spark plug alone—the tension of the secondary circuit is about 30,000 volts, while with two gaps the tension at each gap will be only about 15,000 volts. That this statement is true may be shown by an arc light circuit of 500 volts, with five 100-volt lamps in series with each other in the circuit, and which have a potential of 100 volts each, and not 500 volts, as might be supposed. This explanation, therefore, destroys the claim that the use of the extra gap intensifies the arc or spark at the points of the plug. The real advantage of the extra gap is that the reduction of the voltage, instead of its increase, reduces the tendency of the current to arc across the carbon deposit.

The extra spark gap will only be found effective so long as the carbon deposit upon the insulation of the spark plug is small, or mixed with oil, which increases the resistance of this path. The arcing will continue at the point of the plug until the carbon deposit is rich enough to form a path for the ent[illegible]ume of the current, when the plug will cease sp[illegible] but the extra spark gap will co[illegible]e to arc. [illegible]ntage of the extra spark gap [illegible]t it provi[illegible]ns of seeing whether the secondary circuit is in working order without removing the plug from the cylinder, and the device should be connected in the circuit by a two-point switch to enable it to be thrown in and out of the secondary circuit. The use of the extra spark gap will never absolutely remove the necessity for keeping the insulation of the spark plug in good condition and free from soot or oil. As long as the batteries are strong enough to maintain the full voltage of the primary circuit, just so long will the extra spark gap work successfully in the secondary circuit, and when the electromotive force of the batteries falls below the normal point, it will be found necessary to cut out the extra spark gap, to maintain an efficient spark in the combustion chamber of the motor.

SPARK PLUGS.

The trouble with motors misfiring, is generally due to dirty spark plugs. This is caused by using too much cylinder oil, which, when subjected to the intense heat in the cylinder, turns to carbon. This carbon deposits on the insulated porcelain and the body of the plug, and instead of the current jumping from the point in the body to the point in the porcelain and making a spark, it follows the easiest path, which is the carbon, and does not make a spark at the plug points at all. When this occurs the motor will misfire. The first thing to do when a motor misfires is to test the spark plug. Turn the motor until the battery circuit is closed. Unscrew the spark plug from the motor, then re-connect the wire to it just the same as it was before. Lay the metal part of the plug body on the flywheel or some other unpainted part of the motor, being careful that the metal part of the plug body only touches the motor and that the porcelain part is clear. If the spark jumps in short jerks between the inner end of the porcelain and the interior of the plug body it is sooted and needs cleaning. If it jumps at the points as it should do, the trouble is elsewhere; probably at the battery, loose connecting wires, or the vibrator of the coil is not properly adjusted.

To clean a spark plug properly use a 50 per cent solution of hydrochloric (muriatic) acid, washing the points of the plug with a tooth brush, occasionally dipping the plug into the acid. After cleaning the spark plug in this manner rinse it in water.

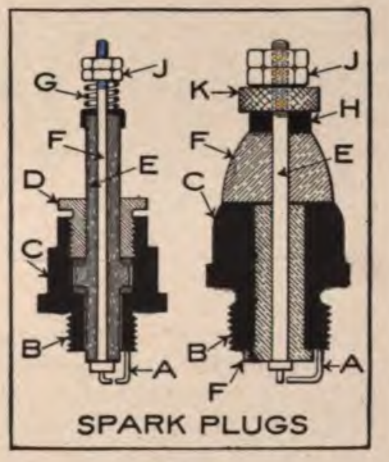


Fig. 114.

A—Platinum point.
B—Thread.
C—Plug body.
D—Bushing.
E—Insulated terminal.
F—Porcelain bushing.
G—Expansion spring.
H—Asbestos washer.
J—Lock nuts.
K—Assembly nut.

Two spark plugs are shown in Figure 114, which, while differing radically in their construction, effect the same purpose, that of producing a spark or arc in the combustion chamber of the motor. The accompanying table and reference to Figure 114, will fully explain the construction of the spark plugs.

Cross-sections of four different forms of spark plugs are shown in Figure 115. All are constructed with a view to make the outside or extraneous path caused by sooting, as long as possible, so as to prevent if possible short-circuiting of the plug from this cause.

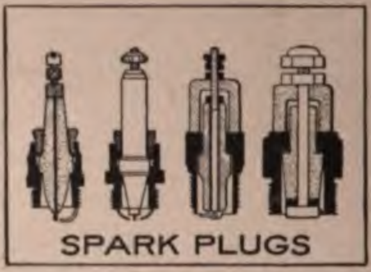


Fig. 115.

Figure 116 shows a form of spark plug in which two extra air-spaces are provided, one between the center rod or terminal and the porcelain bushing, and the other between the porcelain bushing and the shell or body of the plug.

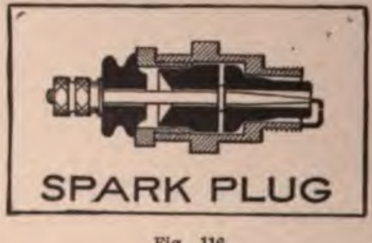


Fig. 116.

The spark plug shown in Figure 117 has a closed chamber around and over the center insulated rod or terminal, this chamber is a part of the body of the plug and forms the other terminal of the plug. It acts as a small combustion chamber and streams of fire are supposed to be thrown from the small openings in the chamber, when the arc or spark occurs therein.

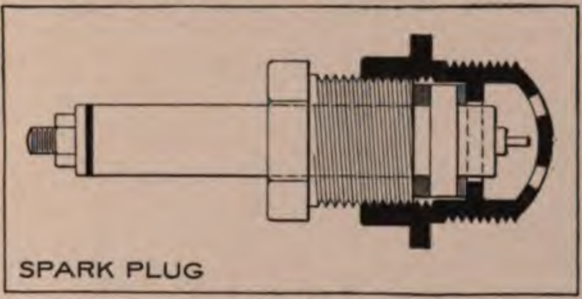


Fig. 117.
SPARK PLUG WITH COMBUSTION CHAMBER.

An exterior view of a form of spark plug in general use is shown in Figure 118.

Spark plugs of American manufacture are made with three different sizes of thread: One-half inch pipe-size, the actual outside diameter of which is 84-100 of an inch, with 14 threads per inch. Three-quarters of an inch diameter, with 18 threads per inch, and 7-10 of an inch diameter, with 17 threads per inch. The last named one is the French or Metric standard thread.

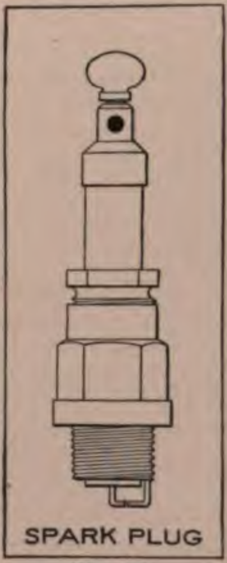


Fig. 118.
SPARK PLUG WITH PORCELAIN INSULATION.

CHAPTER XXX.

SPEED REGULATION.

SPEED REGULATION OF GASOLINE MOTORS.

To secure the greatest efficiency and power of the motor it is necessary to be able to control its speed, and there are various ways to accomplish this object. The range of speed of different motors varies considerably. With small single-cylinder motors it is necessary that the speed should be very great in order to secure sufficient power, while with two and four-cylinder motors this is not necessary, and consequently they are more durable. As a rule the speed varies from about 750 revolutions per minute for the latter to 1,500 for small motors.

There are various methods of governing, which are enumerated and described herewith.

Advancing or retarding the ignition.
Exhaust-valve lifter.
Exhaust-valve regulator.
Regulating the lift of the admission-valve.
Mechanically governing the exhaust-valve.

Advancing or retarding the ignition. This is the method adopted for single and double-cylinder motors, and consists in changing the time at which the spark occurs in the combustion chamber by means of a small lever. If the full force of the explosion occurs in the combustion chamber at the moment when the piston is at the end of its stroke, its effect will be greatest. The duration of pressure on the piston can be reduced by altering the timing of the spark, so that it occurs after the piston has passed the end of the stroke. This is the simplest method, but its proper use depends largely on the skill and experience of the operator. When this method is adopted, a throttle is also used, which enables the operator to regulate the quantity of mixture, and alter the power of the explosion. When the maximum power is required, the throttle is wide open, and the spark advanced to the utmost.

Exhaust-valve lifter. This operates by preventing the exhaust-valve from closing after the exhaust gases have escaped. When the exhaust-valve is held up, no explosive charge is taken into the cylinder.

Exhaust-valve regulator. This method consists in regulating the lift of the exhaust-valve, but does not prevent the valve from closing in the usual manner. It is also used in connection with the spark advance. When the maximum power is required, the exhaust-valve is not interfered with, and opens to its fullest. When less power is required, the exhaust-valve is prevented from opening as much. Consequently the exhaust gases are not fully expelled, and as they partially fill the space in the combustion chamber, a full charge of mixture cannot be admitted through the admission-valve, and the force of the explosion is weakened.

By regulating the lift of the admission-valve. By increasing the strength of the valve spring, the admission-valve is prevented from opening to its fullest extent, and a full charge is not admitted to the combustion chamber.

By mechanically governing the exhaust-valve. This is effected by preventing the cam from lifting the exhaust-valve after an explosion has taken place. This system is adopted on two and four-cylinder motors, and is the one most generally used on cars of European make.

GOVERNORS.

All explosive motors when running under a heavy load slow down or reduce their speed very materially. If the load be entirely or partially removed from the motor very suddenly, it will tend to race. This racing, which causes excessive wear and vibration, is very injurious to the motor. On light cars with small-powered motors, racing is usually prevented by some form of hand control, such as retarding the ignition or throttling the mixture supply. On heavy, high-powered automobiles, racing of the motor is eliminated by the use of some form of centrifugal governor, which controls the motor-speed by one of the three following methods: Retarding the ignition—Throttling the supply of mixture—Preventing the exhaust-valve from opening.

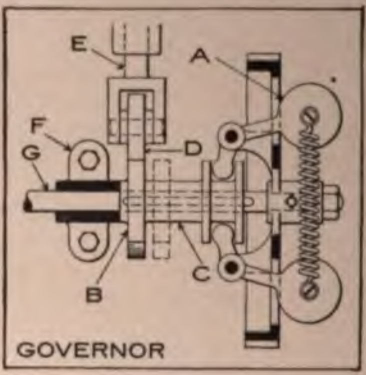


Fig. 119.

Figure 119 shows a form of governor which operates by preventing the exhaust-valve from opening. When the speed of the motor passes its normal limit, the balls A of the governor move out towards the periphery of the gear or wheel which carries them, causing the cam B to be moved to the right by the action of the dogs on the governor arms, which engage in a grooved collar on the sleeve C.

The nose of the cam B is thus kept out of engagement with the roller D until the motor resumes its normal speed, thus preventing the valve-lifter from opening the valve.

Normally the cam is held in position by the springs attached to the governor balls, against the shoulder of the bearing F, which carries the cam shaft G.

THROTTLE.

A throttle is generally placed in the pipe between the carbureter and the admission-valve of the motor, to control the speed and power of the motor by reducing the supply of mixture. It is not by any means an efficient method of governing. The inefficiency of the throttle is due to the fact that the efficiency of an explosive motor depends on the compression.

If the mixture be throttled so as to get a less volume, less compression pressure is the result, as with half the volume of mixture there is only half the compression pressure, therefore about half the efficiency. When running idle or very slowly, the saving of noise is worth the difference.

As it is important to keep up the compression pressure, and therefore the efficiency, throttling is therefore not an economical form of speed regulation.

CHAPTER XXXI.

POINTS TO REMEMBER, AND DON'TS.

If a motor does not ignite its first charge there is a cause for it, and no amount of turning of the crank will locate it. A little common sense will not only locate but remove the cause, and the motor will do its own turning after the first two or four revolutions.

See that every charge the motor takes in is exploded, for which a proper mixture and a good spark are necessary.

Never throttle the mixture so closely that the motor cannot get a full charge every time it needs it.

Always use the very best cylinder oil in the cylinder, and a good quality of lubricating oil in the crank case.

Learn how to properly adjust the vibrator of the coil.

Learn how to set the valve gear correctly.

Learn how to locate and remedy loss of compression in the motor.

Learn how to fix a bearing or piston which has seized.

Always throw the clutch, throttle or spark-advance levers in gradually.

Buy a densimeter, and learn how to test the quality of the gasoline.

Learn how to grind in the valves, also how to fit new piston-rings.

Never leave the car with the motor running. A slight touch of the clutch-lever may cause the car to run away.

See that the water-cooling system has a drain-cock so that the water can be drained in the winter.

Once a month wash out the pipes, water jacket and water tank with a strong solution of common soda or lye. Let the motor run a few minutes before emptying the solution, then empty the tank and pipes and repeat the operation with clean water. This process will tend to insure uniformly effective circulation of the water.

Never pour gasoline near a naked flame. It is safer to extinguish all except electric lights, when filling the gasoline tank of a car.

Always remember that gasoline is a highly volatile and inflammable liquid and its vapor is far more inflammable when mixed with air.

If the motor works well, leave it alone, although it may never seem speedy enough.

That if a motor nearly stops and then goes on again, it is due to lack of gasoline at the carbureter. There is probably dust, dirt, or other deposit at the inlet of the carbureter, which, however, sometimes frees itself. To avoid these troubles gasoline should never be poured into the tank except through a funnel fitted with a fine gauze strainer or a piece of muslin.

That an unusual noise or squeak is evidence of lack of lubrication, and generally foretells a breakdown unless looked after at once.

That air must always find an inlet to the gasoline tank in order that the gasoline may flow out freely, and considerable trouble has been caused by the vent-hole in the cap of the gasoline tank becoming blocked.

That the motor will not run unless the gasoline is flowing from the tank to the carbureter.

That the motor will not start if the switch-plug is in your pocket.

That the motor will not start until the switch is turned on.

That there must always be good electrical connections between the battery, spark coil and spark plug.

That too much lubricating oil must not be used. It causes: the valve to stick, a deposit on the spark plugs, and a poor combustion in the cylinder. Excess of lubricating oil reveals itself in thef orm of smoke at the exhaust.

When the motor is in proper working order, and turned with the crank, a considerable resistance should be felt at every alternate back stroke of the piston. This back pressure should require a considerable effort to overcome when the crank is turned slowly. If the compression of any cylinder is poor, that cylinder will not give its full power.

Finally, remember that if your motor is misfiring or not running properly, the trouble may of its own accord disappear after a little running.

DON'TS.

In the first place don't forget to ascertain the fact that the ignition mechanism is retarded before cranking the motor. Many a sprained wrist and not a few cases of broken heads or arms have been caused by the neglect of this simple precaution. It is a good plan to have the ignition-control spring so actuated that in its normal position it is always retarded.

If the motor should not happen to start the first time, don't forget to keep out of the way of the crank when the motor is stopping. It might take a turn backwards and take the crank with it.

Don't forget to close the battery switch before starting the motor.

Don't allow the motor to stand in such a position that with the battery connected, the vibrator of the spark coil will work. It is almost the same as a short-circuit, and will run down the battery rapidly.

Don't use a match or a small torch to inspect the carbureter. It sometimes leads to unexpected results.

Don't forget to fill the gasoline tank before starting.

Don't smoke while filling the gasoline tank.

Don't take out all the spark plugs when there is nothing the matter, except that there is no gasoline in the tank.

Don't forget to always have an extra spark plug on the car.

Don't allow the motor to race or run fast when out of gear. If the car is to be stopped for a few minutes, without stopping the motor, retard the ignition and also throttle the charge, so that the motor will run as slowly as possible.

Don't fill the gasoline tank too full, leave an air space at the top or the gasoline will not flow readily.

Don't have any open hole in the gasoline tank. When the car is washed water may run in this hole, mix with the gasoline and cause trouble.

Don't put grease in the crank case of the motor, it will clog up the oil holes and prevent the oil from circulating.

Don't fill the gasoline tank by lamp or candle light, something unexpected may happen.

Don't keep on running when an unusual noise is heard about the car, stop and find out what it is.

Don't start or stop too suddenly, something may break.

Don't pour gasoline over the hands and then rub them together. That rubs the dirt into the skin. The proper way to do is to saturate a towel with gasoline and then wipe the dirt off.

Don't forget to examine the steering gear frequently.

Don't fail to examine the pipe between the carbureter and the admission-valve occasionally. The pipe connections sometimes get loose and allow air to enter and weaken the mixture.

Don' forget to see that there is plenty of water and gasoline in the tanks.

Don't fail to clean the motor and all the wearing parts of the car occasionally.

Don't forget to oil every part of the motor where there is any friction, except the valve stems.

Don't spill the gasoline on clothing and then strike a match to light a pipe, some one may be sorry afterwards.

Don't go out for a run without a complete equipment of tools, extra parts, gasoline, and tire repair outfit, or a late return may be expected.

Don't let a willing bystander fill up the gasoline tank with water.

Don't leave the water in the circulating system on a frosty night, except with 40 per cent of glycerine in it, and never when below zero.

Don't start away with the brake on and wonder why the motor is not working well, and in conclusion,

Don't let the starting handle fly off and hit somebody on the chin.

CHAPTER XXXII.

TROUBLES.

CAUSES OF BACKFIRING.

This is a term applied to an explosion or impulse which forces the flywheel of a motor suddenly backwards, that is, in the opposite direction to its proper rotation. The term is sometimes used in connection with explosions which occur in the muffler from the ignition of an accumulation of unburned gases.

Causes. An overheated combustion chamber, due to a poor circulation of the cooling water—causing self-ignition of the charge before the proper time.

Advancing the ignition point too far ahead when the motor is running slowly under a heavy load—flywheel has not sufficient momentum to force the piston over the dead center, against the pressure of the already ignited and expanding gases.

The presence of a deposit of carbon (soot) or a small projecting surface in the combustion chamber which may become incandescent and cause premature ignition.

CAUSES OF BATTERY TROUBLES.

The following are some of the troubles which may occur to a battery:

Loose or coroded terminals will cause a poor electrical contact and failure of the battery to work properly —Remove all thumb-nuts from the binding-posts and clean their contact surfaces thoroughly with emery cloth and screw up firmly after replacing.

Broken wires, or the insulation being worn
part of the wiring of the car. causing a shor

contact with the metal of the frame—The wires should be disconnected from the battery, and the battery tested across its terminals with an ammeter—If the battery is in good condition, reconnect one wire only to the battery and with an extra piece of wire attached to the other battery terminal, test the coil, commutator and switch connections to locate the break and around the metal of the frame for the short-circuit; if not found, reverse the wires and proceed as before. In this manner the break or short-circuit must eventually be discovered.

Weak or run-down batteries cause a motor to misfire and run irregularly—A new set of cells should be used to test the motor with; if it still misfires the trouble must be looked for elsewhere.

Dry batteries wil show practically their full voltage when almost exhausted—A small pocket ammeter should be used to test each cell with. If any of the cells show less than 5 or 6 amperes they should be at once discarded.

Dry batteries polarize very quickly if left on a closed circuit for a few minutes. This is generally caused by the operator of the car omitting to open the switch, when the motor has stopped for some reason or other—If allowed to rest for 20 to 30 minutes, they will generally recuperate sufficiently to enable the operator to start the motor.

Dry batteries will also polarize from too rapid working or too long use without a rest—Two sets of batteries should always be carried on a car and one set at a time used for about 30 minutes, the other set then being used for another 30 minutes. This method will not only give more satisfactory results than by using a single set, but will prolong the life of the batteries.

A dead or exhausted cell in a set of dry batteries will prevent the rest of the cells from working properly—With a small pocket ammeter test the amperage of each cell separately until the dead cell is found—Remove the dead cell and substitute a new one in its place if possible, if not, cut the dead cell out of the battery circuit.

The amperage of a dry battery when new is about 12 to 15 amperes on a closed circuit. When an ammeter only shows 5 or 6 amperes, the cell is practically exhausted and should be replaced by a new one.

The voltage of a storage battery should never be allowed to fall below 1.75 volts per cell. This applies to each individual cell and not a set of cells in one case.

When fully charged a storage battery should show 2.2 volts per cell.

A storage battery should never be allowed to remain in a discharged condition over twelve hours.

Never test or experiment with a storage battery by short-circuiting it across its terminals by means of a piece of wire, an old file or screw-driver.

Troubles with storage batteries, resulting from failure to comply with the above conditions, can only be remedied by the makers.

BREAKDOWNS.

As breakdowns are of frequent occurrence it is of the most importance that all parts of a car that need adjustment or inspection should be readily accessible. Serious breakdowns should never occur on a well kept car.

The usual breakdowns are due to forgetfulness on the part of the operator to make some necessary adjustment on the car, or the lack of tools or extra parts required to repair a break. On a well kept car troubles as a rule [illegible] occur one at a time and those generally at [illegible]vals. A little logical thinking and a few [illegible] in testing usually locates a trouble so that [illegible]moved a start may be made without further [illegible]

The ow[illegible]ar should once in a while undertake the [illegible]ing the car and making the necessary adju[illegible]n.

The mechanic may then, under the instruction of the owner, locate a trouble and remove it in a very short time. A bad breakdown may be described as one which will take over half a day to repair. Many an apparently serious breakdown occurs simply from the fact that the operator fails to examine the condition of the batteries or the state of the spark plugs or commutator before starting on a trip. These details, being very simple and requiring only a few minutes' work, should never be neglected. Before starting on a long trip, to insure getting to the end of the journey without delays, the car should be thoroughly overhauled and anything that might give trouble carefully inspected.

Any one of the following troubles may be the cause of a motor stopping or not working properly:

Soot or grease on the spark plug.
Defective insulation of the spark plug.
Points of the spark plug too far apart.
Contacts of the coil vibrator badly corroded.
Broken wires or loose battery terminals.
Leaky admission or exhaust-valve.
Seized piston or bearing.
Broken valve-stem or valve-spring.
Batteries exhausted.
Defective spark coil.
Poor contact at the commutator.
Defective insulation of the secondary wires.
Broken piston ring.
Stuck piston.
Defective packing.

CLUTCH TROUBLES.

Some of the troubles to which a clutch may give rise are:

Slippage of the contact surfaces of the driving and driven members of a clutch, caused by oil or grease getting between the contact surfaces, or need of adjustment to take up wear or lost motion in the working parts—A little Fuller's earth or French chalk will generally cure the slippage if one of the contact surfaces is of leather. If both are metal, a dose of kerosene will in most cases remove the grease, but on no account use gasoline for this purpose. If the slippage is caused by need of adjustment, so adjust the contact surface of the driving or driven member that the contact surfaces will be closer together than formerly, when apart.

Clutches of the disk or side-drive form usually have the contact surface of the driving member of vulcanized fiber. When badly worn or burnt from too sudden application of the clutch engaging mechanism, slippage will occur, the only remedy for which is new fiber pads.

Clutches of any form, having the contact surface of one of the members leather-covered, which exhibit a tendency to take hold too suddenly, may be remedied by treating the leather surface to a generous application of glycerine or castor oil.

If a cone-friction clutch should stick or seize and all ordinary methods fail to loosen it, with the high speed gear in mesh, push the car backward and forward several times. This will generally free the clutch.

The replacing of the leather on the male member of a cone-friction clutch of the flywheel type is usually a tedious process and one that should be handled by an expert. Owing to the necessity of removing the male member of the clutch from the car, this may in some cases require the complete removal, or at least partial disconnection of the transmission gear.

Always get the new leather from the maker of the car and if possible keep one on hand, to avoid delay when the removal of the leather becomes a necessity.

CAUSES OF MISFIRING.

Misfiring means failing to fire every charge that the motor takes.

One of the most common causes of misfiring is an improper mixture of gasoline and air. Too much air or too much gasoline will cause misfiring.

Batteries which are almost exhausted will give rise to explosions in the motor cylinder which seem all the more violent on account of their irregularity. This should be the time to switch on an extra set of batteries, if one is carried. It is perfectly useless to connect a set of exhausted cells with a new set, either in series or parallel, as it will reduce the new cells nearly to the voltage of the exhausted ones.

Closing the points of the spark plug will help the batteries somewhat and may enable the operator to get the car home.

Examine the battery and all its connections at the terminals, and determine whether the battery is exhausted or not, whether there are broken connections, whether the terminals or other points need cleaning or attention otherwise. Also ascertain whether the fuel is being fed to the motor in proper quantities. It may not be getting enough at each charge or perhaps too much.

Short-circuits and current leakage by contact of a bare place on a wire with some metal portion of the car, or by a spark plug with defective insulation will also cause the motor to misfire. The spark may arc or jump elsewhere than between the platinum points of the plug, rendering a new plug or fresh insulation necessary.

A loose connection in the primary or secondary circuit is another source of misfiring. A loose wire may be in contact and allow one or two explosions to take place. The vibration of the car afterwards may shake the wire loose from its contact and then the motor will misfire. All connections should be carefully cleaned and screwed tight.

If the spark plug is covered with soot or grease misfiring will often result. A spark gap device placed in the secondary circuit will generally overcome this difficulty, but prevention is better than cure and over-lubrication should be avoided and the best grade of cylinder oil used.

CAUSES OF SELF-FIRING.

If the motor should continue to run after the switch has been opened, it is due to an insufficient supply of lubricating oil causing the motor to overheat, or to the presence of soot or some projection in the combustion chamber becoming incandescent. It may also be due to lack of water or to the water circulation working poorly, causing the motor to overheat.

SIDE-SLIP OF MOTOR-CARS.

A wheel with a weight on it when rotating bites into fresh ground as it advances. If the wheel rotate more in proportion than it advances, from any cause, it thereby loosens the particles of dirt beneath it and loses adhesion with the ground immediately under the dirt.

The wheel can now slip sideways as easily as it can slip forwards, particularly when it has the rounded section slightly flattened, which is the case with pneumatic tires. When traveling straight ahead, and with the motor out of gear, skidding does not usually occur. A slight turn given to the steering wheel checks the speed and introduces a side pressure on both front and rear wheels, due to the machine tending to continue its path in a straight line. Generally this side pressure will not cause skidding. If, however, the motor be suddenly thrown in gear, or the brakes suddenly applied, or, what amounts to the same, a large turn is given the steering wheel, the wheels find themselves either rotating more than in proportion to their advance or advancing more than in proportion to their rotation. This immediately causes a loss of adhesion, which, once established, causes the car to skid or side-slip.

CAUSES OF OVERHEATING.

The immediate effect of overheating is to burn up the oil in the cylinders or crank case. This causes a smell of burning and an odor of hot metal. There is sometimes a slight smoke and the motor will make a knocking sound. The cooling water begins to steam, and the car will gradually slow down and finally stop.

The most serious cause of a stoppage on the road is overheating, which causes the lubricating oil to burn up and the piston to expand and grip or seize in the cylinder.

Insufficient lubrication increases the friction between the piston and cylinder, and so generates extra heat. Bad or unsuitable oil may have the same effect.

Too much mixture or too rich a mixture also causes increased heat.

Any failure in the water circulation, unless detected at once, will cause overheating, the results of which may prove very serious. For this reason a careful watch should be kept on the manometer. If this useful device is not fitted, the motor and pipes should be felt by the hand.

As soon as any of the above symptoms are noticed:

The motor should be stopped at once.

Kerosene should be copiously injected into the cylinders and the motor turned by hand to free the piston-rings.

The parts should then be allowed to cool.

Do not pour cold water on the cylinder jackets, for fear of cracking them, but pour the water into the tank so as to warm the water before it reaches the cylinder jackets.

A simple test in the case of an overheated motor is to let a few drops of water fall on the head of the cylinder. If it sizzles for a few moments the overheating is not bad, but if the water at once turns into steam, the case is serious.

Detach the spark plug or plugs, and turn the starting-crank slowly. This draws in cold air and cools the inside of the cylinder and the piston.

KNOCKING OR POUNDING.

Knocking or pounding is an inevitable warning that something is wrong with a motor. It may be due to any of the following causes:

Premature ignition: The sound produced by premature ignition may be described as a deep, heavy pound.

Using a poor grade of lubricating oil will cause premature ignition. The carbon from the oil will deposit on the head of the piston in cakes and lumps, and will not only increase the compression but will get hot after running a short time and will ignite the charge too early, and thereby produce the same effect as advancing the spark too much. If this is the cause the pounding will cease as soon as the carbon deposit is removed from the combustion chamber.

Badly worn or broken piston-rings.

Improper valve seating.

A badly worn piston.

Piston striking some projecting point in the combustion chamber.

A loose wrist-pin in the piston.

A loose journal-box cap or lock-nut.

A broken spoke or web in the flywheel.

Flywheel loose on its shaft.

If the spark plug be placed so as to be exactly in the center of the combustion space, an objectionable knock occurs, which has never been fully explained. In some motors it renders a particular position of the spark control lever unusable; this form of knock disappears either on making a slight advance or retardation of the ignition.

Explosions occurring during the exhaust of admission stroke. This is almost always due to a previous misfire, and it is prevented by stopping the misfires.

If the ignition is so timed that the gases reach their full explosion pressure during the compression stroke, that is, if the spark be unduly advanced when the motor is not running at a high speed, an ugly knock occurs, and great pressure is developed on the crank-pin bearing, wrist-pin, and connecting rod. The result may be the bending or distorting of the connecting rod.

The crank-pin may not be at right angles to the connecting rod. This cause of knock is often hard to find.

The chain may perhaps be loose. This produces a blow if the chain should jump one of the sprocket teeth. The noise is not usually called a knock because it does not recur at uniform intervals. It is dangerous to run with a loose chain, as breakage might precipitate a car down a hill backwards.

The bearings at either end of the connecting rod may be loose. A knock during the explosion stroke, and also at each reversal of the direction of the piston.

If the crank shafe is not perfectly at right angles to the connecting rod, the crank shaft and flywheel will travel sideways so as to strike the crank shaft bearings on one side or the other.

CHAPTER XXXIII.

WATER CIRCULATION.

There are two systems of water circulation in use for cooling the cylinders of explosive motors: The natural or thermal-syphon system and the forced water circulation.

In natural or thermal-syphon water circulation the fact that cold water is heavier than hot water is taken advantage of. A head of water is obtained by placing the tank above the level of the cylinder water-jacket, and as the water in the jacket is heated by the combustion, the cooler water from the tank flows in, forcing the heated water in the tank to take its place, and in this manner an automatic circulation of water is set up. The pipes must be so arranged that they offer every facility for the free circulation of the water, the cold water leaving through a pipe at the bottom of the tank and entering at the lowest point of the cylinder, while the hot water leaves the top of the cylinder and enters the tank at the side near the top. The water circulation, though automatic, is very slow, and for this reason requires a larger body of water to produce as good a cooling effect as a forced circulation.

In forced circulation a rotary pump is used, the direction of the flow being such that the water passes from the pump to the cylinder, thence to the radiator, on to the tank, and then through the pump again, thus completing its circuit. The water in this way gets the maximum cooling effect from the radiator, and the body of water in the tank is kept cool. On account of the high speed of a gasoline automobile motor, and the comparatively small amount of power required to circulate the water, rotary pumps are much used. As there are no valves to get out of order, and high speed is obtainable, this type of pump is very suitable for automobile use.

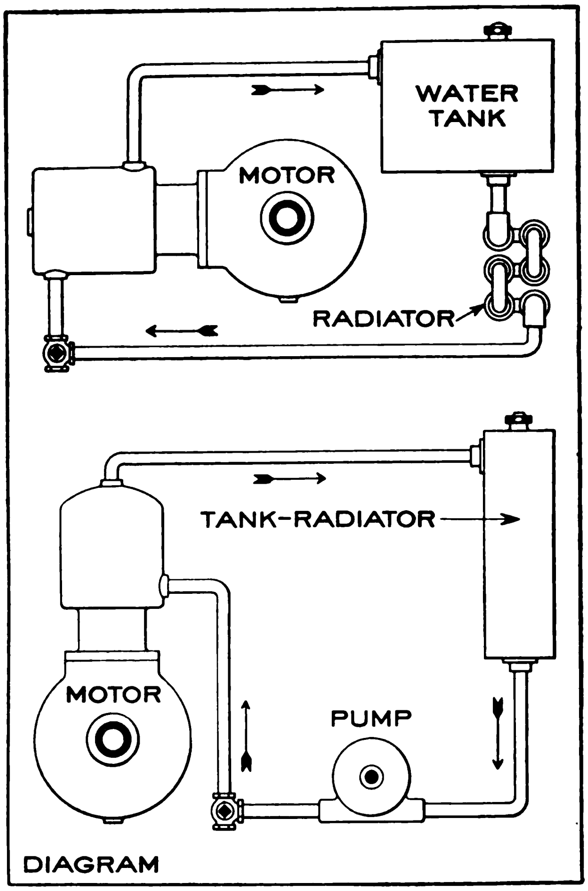


Fig. 120.

The upper and lower views in Figure 120 show the principles of operation of the gravity or thermal-syphon, and the forced or pump circulating systems, respectively.

WATER-JACKETS.

The thickness of the water-jacket space around the cylinder of an explosive motor should not be less than one-eighth of the bore of the cylinder, while the water space surrounding the head combustion chamber of the cylinder should not be less than one-sixth of the cylinder bore.

Bosses for pipe connections to the water-jacket outlet should always be placed at the highest point of the jacket, so as to prevent an air space being formed above the outlet of the jacket. Steam will be formed in this space, and with a gravity or thermal-syphon system is liable to blow or force the water out of the cylinder jacket.

To obtain the greatest degree of fuel economy and motor efficiency the jacket water should be always of a temperature slightly under the boiling point of water.

A leak in the water-jacket of the cylinder of a gasoline motor may be due to one of two causes: Either to spongy places in the metal of the jacket from imperfect foundry work, or to cracks in the jacket from allowing the water to stay in the cylinder jacket during extremely cold weather and the car not in use. The spongy place or crack may be repaired by using one of the two following solutions: Remove the cylinder from the motor and first wash out the inside of the jacket with a 20 per cent solution of sulphuric acid and water, taking care, however, not to let any of the solution get on any of the finished parts of the cylinder. For a spongy place in the jacket use a saturated solution of sal-ammoniac and place the cylinder in such a position that the spongy place is underneath; allow to stand in this position for at least two or three days. Then empty out the solution and leave the cylinder standing for two or three days more, [illegible] the leak has thoroughly rusted. For a cracked water-jacket, keep the water-jacket full of a saturated [illegible] sulphate of copper (blue vitriol) for at [illegible]. The crank is filled up by what is practically an electro-chemical deposit of pure metallic copper.

If steam is seen coming from the relief or outlet of the water circulating system, look for a blockage of the circulation or failure of the pump.

If some of the radiator tubes are cool and others are hot, look to the pump.

To test the pump before starting, run the motor for a few minutes. Then ascertain how long it takes before the top radiator tubes are thoroughly hot. If the heat of the pipes is uniform the circulation is all right.

The circulating pump is used in the belief that it affords a means for regulating the temperature of the jacket water supply, which would not always be the case with a thermal-syphon system. Such is not the case, as the pump, being driven direct from the motor, operates at a speed which varies with the motor speed. On starting the motor, it pumps cold water into the jacket. It pumps slowly at slow speeds, although the motor may be taking a full charge and heating rapidly. It pumps fast at high speeds, although the wind pressure and its consequent cooling effect may be very great. If a circulating pump could be used in connection with a device to control the regulation of the motor temperature, the results would be more satisfactory.

Rotary pumps used in the water circulating system of gasoline automobile motors are of two forms, centrifugal and positive or forced-feed. A positive or forced-feed rotary pump is shown in Figure 121. An annular ring around the pump shaft carries two blades, one of which is hinged to, and the other attached directly to the pump shaft. The outer ends of the blades are supported in the periphery of the annular ring and rotate eccentrically with it. The pump shaft is concentric with the pump chamber, but the annular ring is located eccentrically around the shaft, which drives it by means of the fixed blade on the shaft.

Figure 122 illustrates another form of positive-feed rotary pump, in which the pump shaft is eccentrically located in the pump chamber. A short cylinder which forms a part or portion of the pump shaft, carries two blades in a slotted opening parallel to and coincident with the axis of the pump shaft. These blades are kept in contact with the interior periphery of the pump chamber by means of coil springs, located between the blades as shown. Rotation of the cylinder in the pump chamber causes a sliding or reciprocating action of the blades, due to the pressure of the coil springs between their inner ends.

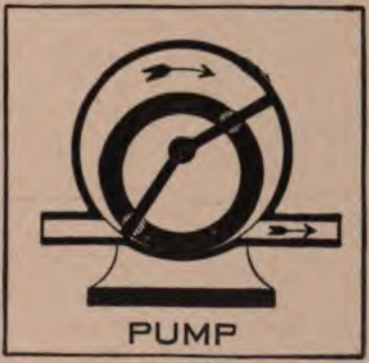


Fig. 121.

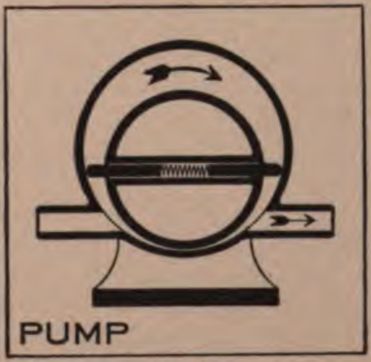


Fig. 122.

The design of a radiator should be such that the maximum of surface is exposed to the air and the greatest freedom afforded for the circulation of the water. As a circle presents the minimum surface, it would appear that a circular pipe is not the best shape for a radiator tube. There are, however, many reasons in favor of the circular section, one of which is the small resistance offered to the flow of the water. With a circular shape the minimum weight of tube is obtained for a given cubic content of liquid, and the greatest strength also for a given weight. A flattened tube section is often used, and is made up to represent in appearance the cellular radiators which have recently come into use. If the cellular radiators are well made, they have the advantage of being more easily cleaned of mud than any other de-

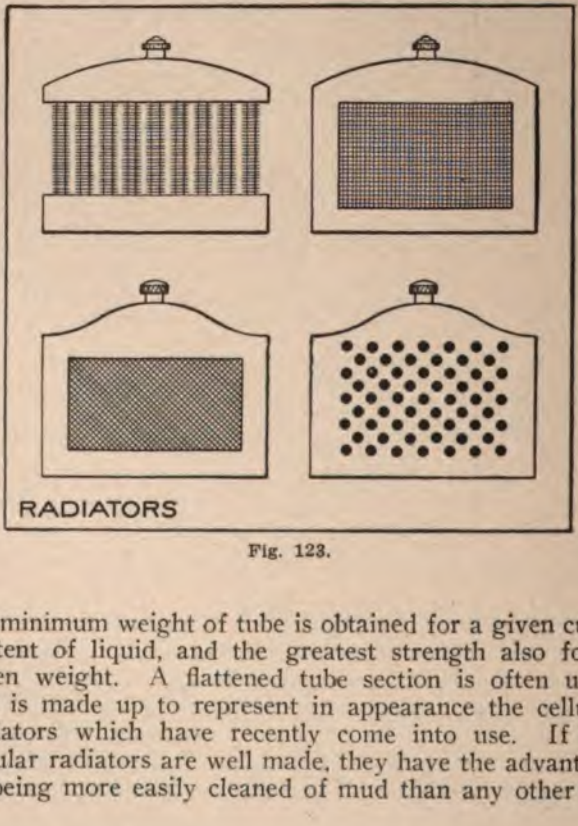


Fig. 123.

sign. The number of joints forming a honey-comb radiator are likely to be a cause of leakage, and such a radiator is far more difficult to repair on the road than the tubular type with radiating fins or disks.

Motors using the thermal-syphon or natural water circulation require about 5 square feet of radiating or cooling surface per horsepower.

Four styles of combination water tank and radiator are shown in Figure 123, having vertical cooling tubes with radiating disks, honey-comb or cellular form of radiation and horizontal tubes, respectively.

CHAPTER XXXIV.

MISCELLANEOUS.

AIR RESISTANCE TO AN AUTOMOBILE.

The power required to move a plane surface, such as the vertical projection of an automobile, against the air, does not become of much importance until the car attains a speed of 10 to 12 miles per hour, when it becomes an important factor.

The horsepower required to propel an automobile against the resistance of the air may be approximately calculated by the following formula. Let V be the velocity of the car in feet per second, and A the projected area of the front of the car in square feet—this may be assumed as the height from the frame to the top of the body multiplied by the width of the seat at the floor line of the car—let HP be the horsepower required to overcome the air resistance, then

$$H.P = \frac{V^3 \times A}{240,000}$$

To simplify the use of the above formula, Table No. 8 gives speeds in miles per hour corresponding to their respective velocities in feet per second and also cubes of velocities in feet per second.

TABLE NO. 8.—CUBES OF VELOCITIES IN FEET PER SECOND.

Miles per Hour of Car.	Feet per Second.	Cube of Velocity in Feet per Second.	Miles per Hour of Car.	Feet per Second.	Cube of Velocity in Feet per Second.
10.2	15	3,375	34.0	50	125,000
13.6	20	8,000	40.9	60	216,000
17.2	25	15,625	47.7	70	343,000
20.4	30	27,000	54.4	80	512,000
27.2	40	64,000	61.3	90	729,000

To ascertain approximately the horsepower that will be necessary to drive a car against a wind of known velocity, the speed of the car must be added to that of the wind, and the required horsepower may be found either by use of the formula given or by reference to Table No. 8, which gives the horsepower per square foot of projected surface required to propel a car against the resistance of the air, with varying speeds in miles per hour or velocities in feet per minute.

The horsepower given by the formula and Table No. 9 simply refers to the additional power necessary to overcome air resistance and not to the actual power required to propel a car at a given speed; this is entirely another matter.

TABLE NO. 9.—HORSEPOWER REQUIRED PER SQUARE FOOT OF SURFACE, TO MOVE A CAR AGAINST AIR RESISTANCE.

Miles per. Hour of Car.	Feet per Second.	Horsepower per Square Foot of Surface.	Miles per. Hour of Car.	Feet per Second.	Horsepower per Square Foot of Surface.
10	14.7	0.013	40	58.7	0.84
15	22.0	0.44	50	73.3	1.64
20	24.6	0.105	60	87.9	2.83
25	36.7	0.205	80	117.3	6.72
30	44.0	0.354	100	146.6	13.12

ELEMENTARY FORMS OF BRAKES.

A brake is a mechanism which is a necessary part of the machinery of an automobile and enables the operator by exerting a slight amount of force on a lever to reduce the momentum of the moving car. Brakes used on automobiles may be divided into three classes: Hub or rear wheel brakes, transmission and differential gear brakes. Brakes have also been applied to the tires of the rear wheels, but have proved unsatisfactory and have been abandoned. The forms of brakes in use are single, or double-acting, foot or hand operated, and of the band, block or expanding ring types.

Figure 124, at A, B and C, shows three forms of the simplest type of single-acting band-brake. This type of brake can be operated successfully with the brake wheel running in one direction only, which is indicated by the arrows in the drawing. If the brakes be operated in the reverse direction to that indicated by the arrows the result will be to jerk the lever or pedal out of the control of the operator of the car.

The three forms of band-brakes shown at A, B and C are all of the same principle, the difference being in the location of the fixed end of the brake-band and the shape of the operating lever. Type D is a form of double-acting block-brake, which is designed with a view to eliminate any strain or side thrust upon the shaft of the brake wheel which may be caused by the braking action of the device. Types E, G and H are three types of double-acting band-brakes, in which the brake may be applied with the brake wheel running in either direction.

Type F is a form of double-acting block-brake, in which the right hand ends of the brake-shoe arms are pivoted to stationary supports, and the left hand ends connected together by means of a link and bell-crank lever as shown in the drawing.

In Figure 125 a form of double-acting block-brake I is shown, which is extremely powerful on account of its peculiar construction, in that it has a double leverage upon the brake wheel, which may be readily seen by reference to the drawing. Types J and K are of the form known as internal brakes and of the expanding ring type, the brakes operating upon the inner surface or periphery of the brake wheel, instead of the outside. They are known as hub brakes, being usually attached to the hubs of the rear wheels of the car. Type L shows a form of block-brake in which the pivoted brake arms are drawn together by the eccentric located on the brake

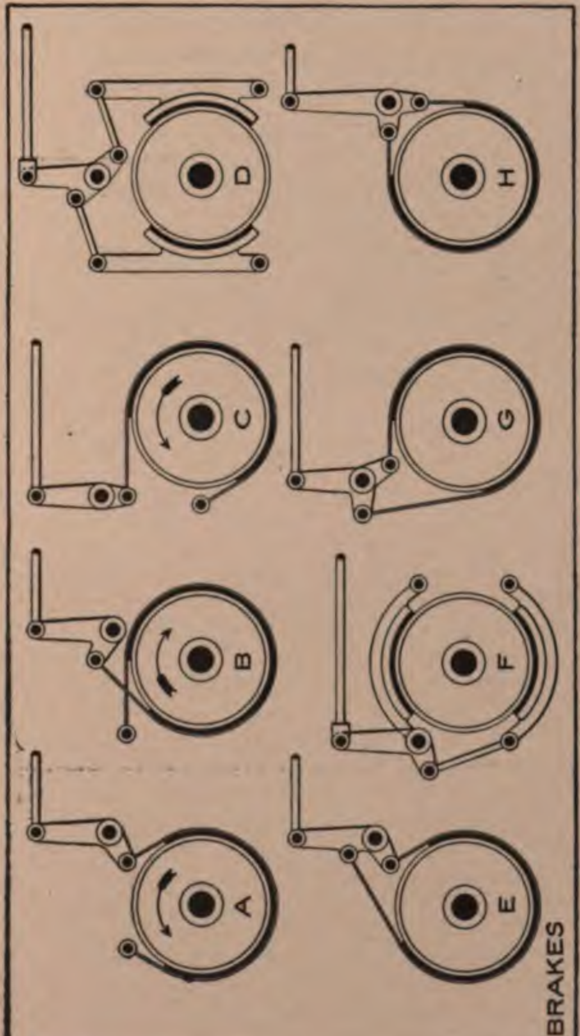


Fig. 124.

lever shaft. When the lever is released the brake-shoe arms are forced apart by the action of the coil spring between the upper ends of the arms.

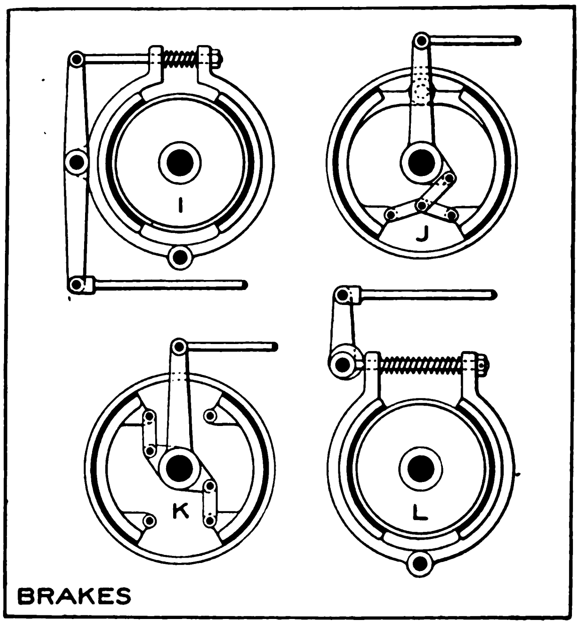


Fig. 125.

COMPARISON OF GAS AND STEAM ENGINES.

The greater thermal efficiency of the gas engine as compared with that of the steam engine and its adaptability to use the poorer and cheaply produced gases made in producer plants, as well as the gases given off from blast furnaces, has resulted in its development and manufacture in units as high as 10,000 horsepower.

Until recently the gas engine, requiring no outside gas-making apparatus, of 100 horsepower was probably the largest unit made. Gas engines up to 500 horsepower are now being made.

The production of great quantities of petroleum in Texas and California chiefly useful for fuel purposes only, and which can be procured at a low price as compared with illuminating oils, has enabled the oil engine in many locations to compete in cost of installation and price of fuel with the most economical types of steam engines.

There can be but little doubt that large modern gas engines, using a good quality of producer or blast-furnace gas free from all impurities, compare very favorably on the score of economy with the steam engine. This arises from the cheapness of the fuel in the first place, from the superior calorific value of gas over steam, and the more efficient utilization of the heat in the gas engine.

COMPARISON OF HORIZONTAL AND VERTICAL ENGINES.

Accessibility of the parts in a horizontal engine is always considered a great advantage. The piston can always be seen and can be taken out of the cylinder and cleaned and replaced easily in this style of engine, while in a vertical engine it is necessary to remove the cylinder cover and sometimes the cylinder to gain access to the piston, and it is also necessary to have sufficient room above the top of the cylinder to lift the piston and connecting-rod out. The connecting-rod is more accessible for adjustment both at the crank-pin end and at the piston end in the horizontal type. This difficulty, however, has been overcome by arranging a removable plug in the piston head, which when taken out allows access to the piston end of the connecting-rod.

Vertical engines for places where space is restricted and where sufficient head room is available have the greater advantage of occupying less floor space than a horizontal engine. The mechanical efficiency of a vertical engine is, however, somewhat greater, the friction of the piston being less than in the horizontal type of engine.

Sometimes the vertical type of engine can only be be used, but for ordinary uses the horizontal type of engine seems to be most in favor, one important point being the difficulty of suitably arranging the carbureting or vaporizing devices in the vertical type of engine, which are usually placed close to the cylinder, and are not so fully under the control of the attendant as in the horizontal engine.

COMPARISON OF TWO AND FOUR-CYCLE GAS ENGINES.

The trend in design of large-size gas engines using producer or blast-furnace gas is to the two-cycle principle of operation. Where the four-cycle principle is adhered to, two or more cylinders are necessary. As the four-cycle single-cylinder engine obtains an impulse only once in two revolutions, consequently during three idle strokes of the piston the power and speed of the engine must be maintained by the momentum of the flywheels, necessarily enormous in an engine of 500 horsepower or over, for the power obtained, in comparison with the flywheel of a steam engine of the same capacity. With the two-cycle engine of large horsepower, in which an impulse is obtained each revolution of the crank shaft, nearly double the power is said to be developed as compared with the four-cycle engine of the same size. The mechanical efficiency is increased, owing to the reduced weight of the flywheels, and the weight and cost of the engine per horsepower is reduced.

The difficulty of procuring proper combustion in the two-cycle oil engine, where crude oil is used, has, however, not yet been entirely overcome.

It may be stated that the larger size two-cycle engines, to compete with the four-cycle gas engine in cost of fuel, can do so only when a cheap grade of fuel is used. To use such fuel, it is imperative that proper combustion should take place in the cylinder.

COMPRESSED AIR STARTERS.

On account of the difficulty of starting large engines by hand, self-starters are used for engines over 10 to 12 horsepower, and a great variety of methods are in use. Compressed-air starters are simple and consist usually of a hand or power air pump, which forces air under pressure into a tank.

The air tank is connected with the cylinder, and the flywheel being turned till the engine is in a position to start, that is when the crank is just above the dead center, the compressed air valve is then opened and kept open until the piston approaches the end of its stroke. This operation is repeated once or twice, if necessary, to set the engine in motion.

A number of devices are also in use, in which charges of gas and air are forced into the engine cylinder, and ignited by a separate and special device, the operation being repeated till the ordinary ignition mechanism comes into play. Exhaust gases stored by the engine itself, under pressure in a reservoir, are also used.

DIAMETRAL PITCH SYSTEM OF GEARS.

Table No. 10 gives the necessary dimensions for laying out and cutting involute tooth spur gears from No. 16 to No. 1 diametral pitch. Formulas are also given so that if the number of teeth and the diametral pitch are known, the pitch diameter can be ascertained, also the diametral pitch, outside diameter, number of teeth, working depth, and clearance at bottom of tooth:

P =Pitch diameter in inches.
D =Diametral pitch.
W =Working depth of tooth in inches.
N=Number of teeth.
O =Outside diameter in inches.
C =Circular pitch in inches.

(1) Pitch diameter$=\frac{N}{D}$

(2) Outside diameter$=P+\frac{2}{D}$

(3) Diametral pitch$=\frac{N}{P}$

(4) Circular pitch$=\frac{3.142}{D}$

(5) Working depth of tooth$=\frac{2}{D}=2\div D$

(6) Number of teeth$=P\times D$

(7) Thickness of tooth$=1.571\div D$

(8) Clearance at bottom of tooth$=\frac{C}{20}$

For example: Required, the pitch diameter of a gear with 20 teeth and No. 5 diametral pitch. From Formula No. 1, as the pitch diameter is equal to the number of teeth divided by the diametral pitch, then 20 divided by 5 equals 4, as the required pitch diameter in inches.

What is the outside diameter of the same gear? From Formula No. 2, as the pitch diameter is 4 inches, and the diametral pitch No. 5, then 4 plus 2-5 equals 4 2-5 as the proper outside diameter for the gear..

What would be the diametral pitch of a gear with 30 teeth and 5 inches pitch diameter? From Formula No. 3, 30 divided by 5 equals 6, as the diametral pitch to be used for the gear. In this manner by the use of the proper formula any desired dimension may be obtained.

TABLE No. 10.—DIMENSIONS OF INVOLUTE TOOTH SPUR GEARS.

Diametral Pitch.	Circular Pitch.	Width of Tooth on Pitch Line.	Working Depth of Tooth.	Actual Depth of Tooth.	Clearance at Bottom of Tooth.
1	3.142	1.571	2.000	2.157	0.157
2	1.571	0.785	1.000	1.078	0.078
3	1.047	0.524	0.667	0.719	0.052
4	0.785	0.393	0.500	0.539	0.039
5	0.628	0.314	0.400	0.431	0.031
6	0.524	0.262	0.333	0.360	0.026
7	0.447	0.224	0.286	0.308	0.022
8	0.393	0.196	0.250	0.270	0.019
10	0.314	0.157	0.200	0.216	0.016
12	0.262	0.131	0.167	0.180	0.013
14	0.224	0.112	0.143	0.154	0.011
16	0.196	0.098	0.125	0.135	0.009

The following formulas will give the horsepower that may be transmitted by gears with cut teeth of involute form and of various metals.

H.P=Horsepower.
P=Pitch diameter in inches.
C=Circular pitch in inches.*
F=Width of face in inches.
R=Revolutions per minute.

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* The circular [illegible] ding to any diametral pitch number may be [illegible] the constant by 3.1416 by the diametral pitch.

Example: What [illegible] pitch in inches corresponding to No. 6 diametral [illegible]

Answer: The [illegible] ing 3.1416 by 6 gives 0.524 inches [illegible] the required [illegible]

$$\text{H.P}=\frac{P\times C\times F\times R}{90} \quad \text{(Annealed tool steel.)} \quad (1)$$

$$\text{H.P}=\frac{P\times C\times F\times R}{140} \quad \text{(Mach. steel or Phosphor Bronze.)} \quad (2)$$

$$\text{H.P}=\frac{P\times C\times F\times R}{410} \quad \text{(Cast Brass.)} \quad (3)$$

$$\text{H.P}=\frac{P\times C\times F\times R}{550} \quad \text{(Cast Iron.)} \quad (4)$$

Example: Required, the horsepower which a tool steel pinion, 2 inches pitch diameter, 1 inch face and No. 10 diametral pitch, will transmit at 900 revolutions per minute.

Answer: From the table the circular pitch corresponding to No. 10 diametral pitch is 0.314. Then by Formula No. 1, $2\times 0.314\times 1\times 900$ equals 565.2. This, divided by 90, gives 5.29 horsepower.

FIRE INSURANCE.

The following are the general requirements of the various boards of fire underwriters for the installation and use of oil engines:

Location of Engine. Engine shall not be located where the normal temperature is above 95 degrees Fahrenheit, or within ten feet of any fire.

If enclosed in room, same must be well ventilated, and if room has a wood floor, the entire floor must be covered with metal and kept free from the drippings of oil.

If engine is not enclosed, and if set on a wood floor, then the floor under and three feet outside of it must be covered with metal.

Oil Feed Tank. If located inside of building, shall not exceed five gallons capacity, and must be made of galvanized iron or copper, not less than No. 22 B. & S. Gauge, and must be double seamed and soldered, and must be set in a drip pan on the floor at the base of the engine.

FLYWHEELS.

One of the first and most important considerations in connection with the construction of a gasoline automobile motor is the proper diameter and weight of the flywheel. If the diameter and weight of the flywheel be known, the speed of the motor or its degree of compression will become a variable quantity. On the other hand, if the speed of the motor and the degree of compression be fixed, the diameter or weight of the flywheel rim must be varied to suit the other conditions. If the speed of the motor and its degree of compression be known, the diameter of the flywheel or the weight of the flywheel rim may be readily ascertained from the following formulas.

The weight of the rim of the flywheel is the only portion which enters into the following calculations, the weight of the web or spokes and hub being neglected.

Let M.P be the mean pressure of the compression, and A the area of the cylinder in square inches.. If S be the stroke of the piston in inches, and N the number of revolutions per minute of the motor, let D be the outside diameter of the flywheel in inches and W its required weight in pounds, then

$$W = \frac{M.P \times A \times S \times N}{2560 \times D}$$

A motor that is intended to operate at a slow rate of speed and consequently with a high degree of compression, will require a flywheel of much greater diameter and weight than a high speed motor of the same bore and stroke. It may be well to remember that within certain limitations the diameter and weight of a flywheel should be as small as is possible, as an increase in either means a reduction in motor speed and a consequent loss of power.

To ascertain the diameter of a flywheel when all other conditions are known, if D be the required diameter of the flywheel in inches, then

$$D=\frac{M.P\times A\times S\times N}{2560\times W}$$

If it be desired to run a motor at a practically uniform speed and with only a slight fluctuation or variation in the velocity of the flywheel, if W be the required weight of the flywheel and x be the allowable fluctuation of the flywheel in revolutions per minute above and below its normal speed, then

$$W=\frac{M.P\times A\times S\times N}{365\times x}$$

It is sometimes desirable to know the amount of energy or horsepower which may be stored in the rim of a flywheel of known diameter and weight, with a given speed. If H.P be the horsepower stored in the rim of the flywheel, then

$$H.P=\frac{D^2\times W\times N}{792,000}$$

The safe velocity for the rim of a cast iron wheel is taken at 80 feet per second. Let N be safe speed of the flywheel in revolutions per minute, then

$$N=\frac{18,335}{D}$$

M.P=Mean pressure.
A=Area of cylinder in square inches.
S=Stroke of piston in inches.
N=Number of revolutions per minute.
D=Diameter of flywheel in inches.
W=Weight of flywheel in pounds.

The flywheel should be balanced as accurately as is possible before mounting on the crank shaft. In the first place set the crank shaft on two perfectly straight parallel bars, one bar under each end. Then attach the connecting rod and piston to the crank and turn the shaft until the crank jaws are parallel with the floor, or in other words, at right angles to a perpendicular line drawn through the center of the shaft. Place a scale under the crank pin or use a hanging scale attached to some rigid support above the pin and connect it to the crank pin by a wire or cord sufficiently strong to carry the weight. Then find the weight of the parts according to the scale and attach the same amount to the flywheel at the same distance from the shaft on the side opposite the crank, and the result will be a fairly balanced motor. It is impossible to obtain a perfect balance, but the above method will greatly assist in reducing the vibrations of the motor.

OPERATION OF FOUR-CYCLE ENGINE.

A four-cycle engine has only one working stroke or impulse for each two revolutions. During these two revolutions which complete the cycle of the engine, six operations are performed:

1. Admission of an explosive charge of gas or gasoline vapor and air to the cylinder of the engine.
2. Compression of the explosive charge.
3. Ignition of the compressed charge by a hot tube or an electric spark.
4. Explosion or extremely sudden rise in the pressure of the compressed charge, from the increase in temperature after ignition.
5. Expansion of the burning charge during the working stroke of the engine piston.
6. Exhaust or expulsion of the burned gases from the engine cylinder.

As pressure increases with a rise in temperature, which in an engine the moment after ignition has taken place is about 2,700 degrees Fahrenheit, the higher the temperature of the ignited gases, the greater would be the pressure. As this pressure is expended in work on the engine piston, the whole of it might, if expansio the burning gases were continued long enough, be utilized. Full utilization of the expansion of the gases is impossible from a mechanical point of view. The expansion of the gases should be as rapid as possible, as the faster the piston uncovers the cylinder wall, the less time will be left for the transmission of heat or energy to the cylinder wall. Gasoline vapor or gas in themselves are not combustible, but must be mixed with a certain amount of air before ignition and consequent combustion can be effected. The combustion of the gases is not instantaneous, but continues during the entire working stroke of the engine piston.

Figure 126 gives four diagrammatic views of the operation of a four-cycle gas or oil engine. It shows an inlet-valve A, valve-openings B, cylinder C, cam D, exhaust valve E, combustion chamber F, piston G, valve springs H, crank case J, connecting-rod K and crank-pin L.

Diagram No. 1 shows the piston about to draw in a charge of explosive mixture, the suction or drawing in of the charge continues until the piston has reached the position shown in Diagram No. 2. Then the piston returns until it arrives at the position shown in Diagram No. 3, compressing the charge of mixture during this operation. Just before the piston has reached the end of its travel in this direction, the charge under compression is ignited either by an incandescent tube or by an electric spark and the force of the explosion drives the piston back to the position shown in Diagram No. 4, when the exhaust-valve is opened by means of the cam and valve-lifter rod. The exhaust-valve remains open until the piston has reached the position shown in Diagram No. 1. Then it closes, the piston again commences to draw in a charge of explosive mixture and the cycle of operation of the engine is repeated. As it requires four strokes of the piston or two complete revolutions of the crank shaft to complete the cycle, there is consequently only one impulse every two revolutions or one working piston stroke out of four.

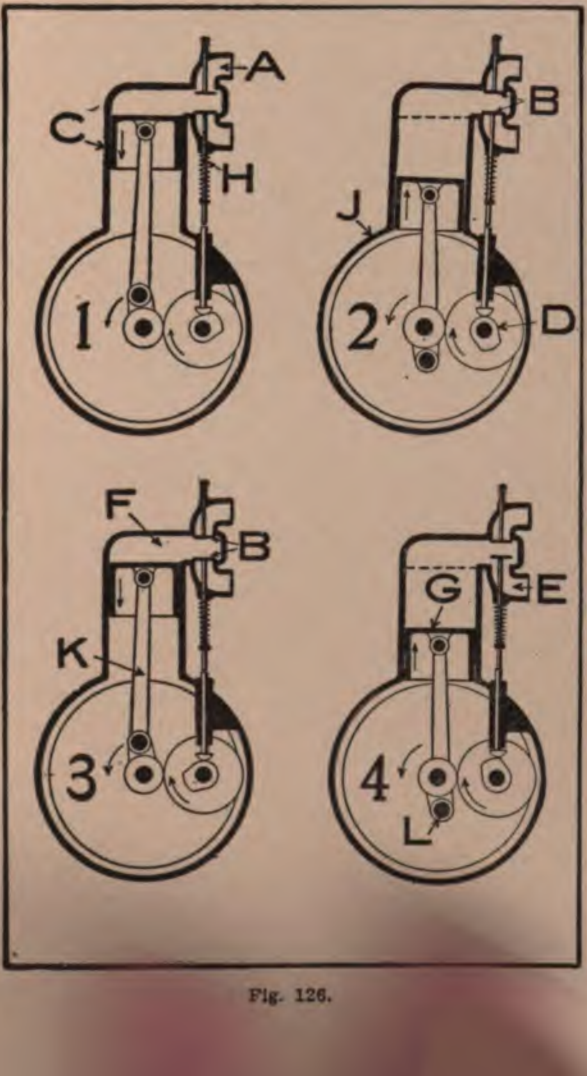


Fig. 126.

GASOLINE TRACTION ENGINE.

From the result of experience it has been found that gasoline traction engines require a double cylinder construction, as the duty of the engine is to not only drive the traction gearing, but to propel itself over the roads. It is found that for successful work in the field, which has heretofore been occupied by the steam traction engine, a gasoline engine of from 30 to 40 brake horsepower must be used. In an engine producing this amount of power in a single cylinder, the sudden impulses at intermittent intervals would require for successful operation a train of gearing so large and heavy that it absolutely precludes the possibility of making any reasonable construction. When, however, the engine develops the same power in two cylinders with impulses twice as frequent and only one-half as strong, it is possible to make a train of gears which will transmit the full power of the engine and consequently a strong and successful gasoline traction engine. The builders of gasoline traction engines have heretofore used engines of the old models, and while these engines have served their purpose in stationary work and to some extent in portable work, their use has not been as satisfactory as with the two-cylinder style of gasoline traction engine.

INTERNAL-EPICYCLIC GEAR

It is often desired to ascertain the speed of rotation of the different members of this form of gearing. To calculate their speeds, the following formulas are given, which, by reference to the letters designating the different parts in Figure 127 may be readily solved.

Let R be the revolutions per minute of the disk or spider carrying the pinions D.

Let N be revolutions per minute of the gear E.

Let G be the revolutions per minute of the internal gear F.

When the internal gear F is locked and gear E rotating, the speed in revolutions per minute of the disk or spider carrying the pinions D is

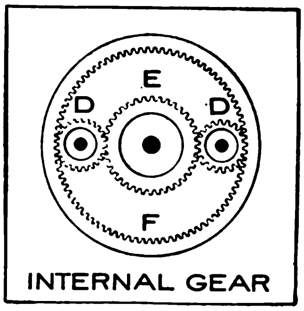


Fig. 127.

$$R=N\left(\frac{E}{E+F}\right)$$

If the internal gear be locked and the spider carrying the pinions D be rotated, then the speed in revolutions per minute for the gear E will be

$$N=R\left(\frac{E+F}{E}\right)$$

If the spider carrying the pinions D be held rigid and the gear E be rotated, the speed in revolutions per minute for the internal gear F is

$$G=\left(\frac{N\times E}{F}\right)$$

If the pitch diameter of the gear is not readily obtainable, the number of teeth in each gear may be used instead, as the result will be exactly the same.

SPEED IN MILES PER HOUR.

The following table gives the speed in miles per hour, from 27.69 to 120 miles per hour, for a mile covered in any given interval of time in minutes and seconds, between 2:10 and 0:30.

TABLE NO. 11.—SPEED IN MILES PER HOUR.

Time in Minutes and Seconds.	Speed in Miles per Hour.	Time in Minutes and Seconds.	Speed in Miles per Hour.	Time in Minutes and Seconds.	Speed in Miles per Hour.	Time in Seconds.	Speed in Miles per Hour.
2-10	27.69	1-38	36.73	1-15	48.00	52	69.23
2-05	28.80	1-37	37.11	1-14	48.65	51	70.58
2-00	30.00	1-36	37.50	1-13	49.32	50	72.00
1-59	30.25	1-35	37.89	1-12	50.00	49	73.47
1-58	30.51	1-34	38.29	1-11	50.70	48	75.00
1-57	30.77	1-33	38.71	1-10	51.43	47	76.59
1-56	31.03	1-32	39.13	1-09	52.17	46	78.26
1-55	31.30	1-31	39.56	1-08	52.94	45	80.00
1-54	31,58	1-30	40.00	1-07	53.73	44	81.82
1-53	31.86	1-29	40.45	1-06	54.54	43	83.72
1-52	32.14	1-28	40.91	1-05	55.38	42	85.71
1-51	32.43	1-27	41.38	1-04	56.25	41	87.80
1-50	32.73						
1-49	33.03	1-26	41.86	1-03	57.14	40	90.00
1-48	33.33	1-25	42.35	1-02	58.06	39	92.31
1-47	33.64	1-24	42.86	1-01	59.02	38	94.74
1-46	33.96	1-23	43.37	1-00	60.00	37	97.29
1-45	34.28	1-22	43.90	59	61.02	36	100.00
1-44	34.62	1-21	44.44	58	62.07	35	102.86
1-43	34.95	1-20	45.00	57	63.16	34	105.88
1-42	35.29	1-19	45.57	56	64.28	33	109.09
1-41	35.64	1-18	46.15	55	65.45	32	112.50
1-40	36.00	1-17	46.75	54	66.67	31	116.63
1-39	86.36	1-16	47.37	53	67.92	30	120.00

RUNNING GEARS.

A complete running gear includes the frame, springs, wheels, motor, speed-change-gear, axles and the machinery of the car except the body. The French word, Chassis, is sometimes used to designate a running gear, but its use is not correct, as strictly speaking the term, chassis, applies to the frame only, or at the most to the frame and springs.

Figure 128 illustrates a vertical section of a running gear equipped with a vertical four-cylinder motor, and longitudinal propeller-shaft drive, by bevel gearing to the live rear axle.

A plain view of a running gear with double side-chain drive and rigid rear axle is shown in Figure 129. The motor is also of the vertical four-cylinder form. The water cooling system in both cases is by rotary pump, combination tank and radiator, and fan as shown.

SPEED OF GASOLINE MOTORS.

In explosive motors the products of combustion diminish in about the ratio of the increase of speed. The pressures and temperatures at admission and exhaust are variable, and depend on the speed and the mean temperature of the cylinder wall. The compression pressure decreases in proportion to the increase of speed, owing to the diminished volume of mixture at higher speeds. If it were not for this the power of a motor of given bore and stroke would go up in the same proportion as the speed.

An automobile motor differs fundamentally from the stationary form by reason of its being required to run at variable speeds. If the valves are well designed, nearly the full volume of gas should be taken in at higher speeds and the compression will actually improve at higher speeds owing to the diminished time for leakage round the piston-rings. This tends to improve the fuel economy of the motor.

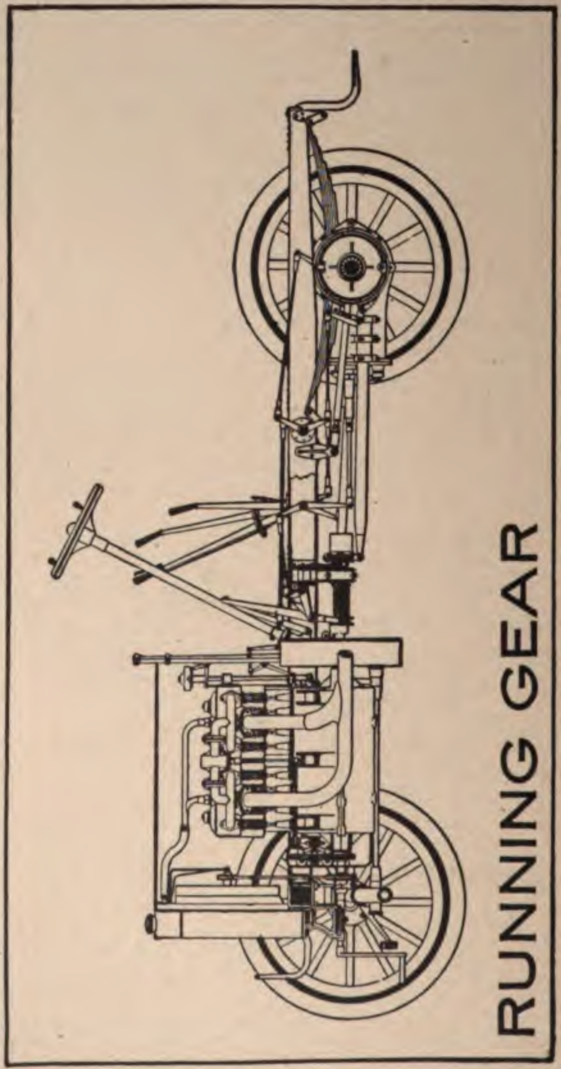
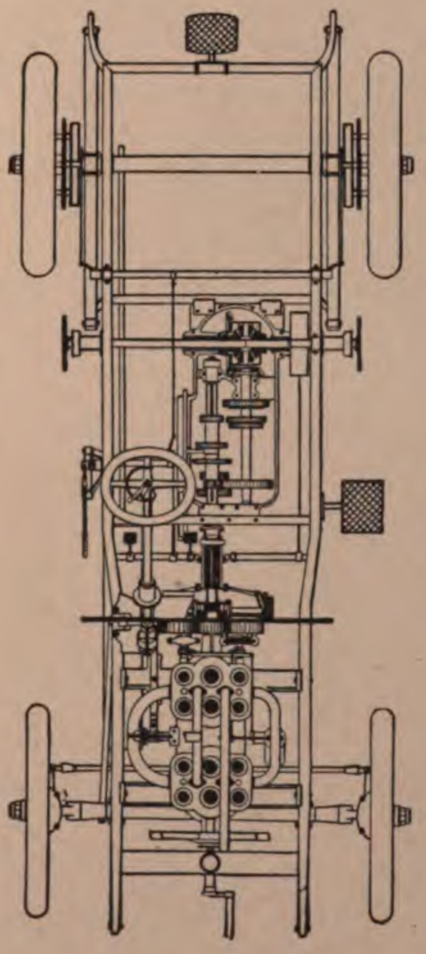


Fig. 128.



RUNNING GEAR

Fig. 129.

TRACTION OF DRIVING WHEELS.

A horse which exerts a pull of about 375 pounds continuously for an hour and goes a distance of one mile in an hour is working at the rate of one horsepower. If for any reason the horse is unable to exert as much as 375 pounds pull when going at the rate of one mile per hour, he is thereby prevented from working at the rate of one horsepower.

The same rule applies to a motor car. When the road is not slippery there may occur a condition which does not appear with horse traction: that the tires fail to adhere to the ground owing to insufficient weight on the driving wheels. In such a case it is impossible for the motor-car to exert a push of 375 pounds without skidding the wheels, and thus it would be impossible for it to work at the rate of one horsepower. With underpowered motor-cars this difficulty does not occur, but to develop 10 horsepower at the rims of the driving wheels while covering the ground at the rate of one mile per hour, the car must exert a push on the road of 3,750 pounds. This is, on touring cars of ordinary weight, impossible, because the weight on the driving wheels is invariably less than 3,750 pounds, while the adhesion with the road is only a fraction of the weight on the rear wheels. As the speed rises, however, the push necessary for the development of 10 horsepower goes down until at 10 miles per hour a push of 375 pounds means 10 horsepower.

Thus a 40 horsepower car, if it could start work with the activity of forty horses, would, while it was moving at one mile per hour, exert no less a push than 40 x 375, which is equal to 15,700 pounds. This tremendous push is rendered impossible by the fact that the wheels of a car weighing 2,000 pounds only grip the ground enough to exert about 750 pounds push. Beyond this point they will skid.

This shows that a high-powered car, when the car is moving slowly, cannot develop its full power unless the road wheels are capable of adhering to the ground sufficiently to transmit this power. As a rule only about 0.6 of the weight of the car is on the driving wheels, and of that only 0.625 is available for the adhesion (owing to the coefficient of friction between rubber and road being 0.625). So a 10 horsepower car weighing 2,000 pounds cannot exert its full power when the car is starting, nor until it is traveling at 5 miles per hour.

It would be wrong to contend that on all cars having the weight distributed as at present, a 60 horsepower motor is useless, but it is needless to say that the output of such a motor is not available at starting or at any speed under 30 miles per hour, although the whole power is more needed then than at any other time. The remedy which suggests itself is by using all the adhesion of the car, that is, to drive with all four wheels.

CHAPTER XXXV.

MARINE MOTORS.

TYPES OF GASOLINE ENGINES.

When choosing a gasoline engine for operating a boat there are a number of points to be dealt with. The gasoline engine is expected to be in working order at all times and it must never break down. If it does, the operator will decry the gasoline engine, its builders and all who have anything to do with it. If a steam engine breaks down, there may be some strong words used with reference to its maker, but as a rule nothing is said against the steam engine as a prime mover, for the simple reason that we are accustomed to its vagaries.

While much more is expected of the gasoline engine than of the steam engine, the previous assertion is none the less true that reliability of operation is the primary consideration. Economy of fuel, which is a matter of first importance with all prime movers on land, becomes a secondary requirement as far as the marine gasoline engine is concerned, and more especially when these engines are to be used for small powers. It is a mistaken notion that anyone can operate a gasoline engine. A child will get on very well after being taught, and until something happens. Then comes the necessity for a man with reasoning powers that are well developed and with a clear head. All kinds of things may happen to a vessel, if its motive power gives out. A great many things may happen to a gasoline engine in indifferent hands.

Before going further it may be necessary to explain briefly the principles of operation of the two types used for marine purposes. These types are the four-cycle engine, in which there is but one impulse for each two revolutions of the crankshaft, and the two-cycle engine, in which an impulse occurs at each revolution of the crankshaft. Of the two, the four-cycle engine is most used for stationary purposes, but in marine practice the two-cycle engine is in the lead. Although not generally considered as economical of fuel as the four-cycle engine, it can be built much lighter for the same power, and the great frequency of the impulses makes it much steadier in operation. This can perhaps be realized better when it is remembered that a single cylinder steam engine receives an impulse at every stroke of the piston, or two impulses at every revolution of the crankshaft, while the four-cycle gasoline engine receives but one impulse to two revolutions, or one impulse to four in the steam engine. The steam engine also receives two impulses during the same time that the two-cycle engine receives one.

MULTIPLE-CYLINDER ENGINES.

Multiple-cylinder engines of the two-cycle type have until quite recently been constructed by adding successively separate engines. While these in a great many cases have given satisfaction, they have not as a whole been satisfactory. The chief trouble being that when operated by one carbureter, they have been inclined to flood in the after-cylinders. The gasoline gas being of greater specific gravity than air, has a tendency to go to the lowest point, which in the majority of boats would be the after-cylinders. The distance apart of the separate engines also tending to condense the vaporized gasoline, flooding the crank bases of the engines with the consequence that no two of the cylinders have a uniform mixture of gas, and in many cases the after cylinders refuse to work at all. In order to avoid these difficulties, many multiple-cylinder engines have separate carbureters for each crank case. While this is all right in theory it is not good practice, as it is difficult to obtain correct regulation of each cylinder when they are all in operation. There have been placed on the market a number of multiple-cylinder engines with the cylinders in one integral casting and surrounded by one water-jacket. By this means the cylinders are brought very close together, using one carbureter, the connections from it to the engines by this plan are very short and compact. These engines in their very best form are not adapted to be operated by a novice. Owing to their high speed and the number of moving parts, it is very difficult to detect and locate troubles of any kind, and determine in which cylinder the trouble exists. The four-cycle multiple-cylinder engine is an entirely different proposition, and especially, the double cylinder, which is very successful. The two-cylinder four-cycle engine produces the same results and only has the same number of movements as in the single-cylinder two-cycle, therefore a four-cycle four-cylinder is equivalent to a two-cylinder two-cycle engine. One of the principal troubles of the mutiple-cylinder high speed engine is the ignition, as it is very hard on generators and batteries.

SELECTING A BOAT ENGINE.

The thing for the prospective purchaser to do is naturally to write to different makers of gasoline engines and obtain their catalogues and price lists. It will be found that each one is building the best engine on earth, if his story is to be believed. It is a sad truth, indeed, that there are many poor gasoline engines offered for sale in the open market. Several catalogues will probably contain an engine very nearly the size which has been selected for the new boat. If the catalogues received contain testimonials from persons who live in the vicinity, make it a point to call on them, and have a private talk with them about their engines.

Find out how much the engine has been run, and obtain a narrative of all experiences with the engine when running. Find out the longest as well as the shortest period of time it has taken to get the engine started, and how long it has been run at any one time without stopping. Find out if the engine is addicted to thumping or pounding in any part of the mechanism, and whether such a condition is of frequent occurrence, or only occasional, and also how long the ignition apparatus will last. If it be found that the engine transmits very little vibration to the boat, it may be presumed that the engine is well balanced.

Another way to tell whether an engine is in good balance is to see if it will run for quite a little time after the ignition current has been cut off. Of two engines, that are of the same size, and equally well lubricated, and which have the same friction resistance, the engine will run the longer after power is shut off that is the better balanced. When resting the hand upon the cylinder head while the engine is running idle, if a knock is perceptible it is a certain sign that it is out of balance.

If the engine is counterbalanced in the flywheel instead of on the crank jaws it gives a twisting movement to the shaft, and the balancing is imperfect. A well-balanced engine should have the counter-weight as nearly opposite the crank pin as it is possible to place it. In a two-cylinder engine with the crank pins at 180 degrees, or in a three-cylinder engine with the cranks at 120 degrees, a balancing effect is obtained which is much better than that produced by a counter-weight. It is the custom with some builders to put the crank pins on the same side of the shaft for a two-cylinder engine, for the reason that the impulses are better distributed. It is generally admitted that a better mechanical balance is obtained with the crank pins at 180 degrees and in a vertical two-cylinder engine of the four-cycle type with an enclosed crank case, the latter arrangement avoids the pumping action that occurs when the cranks are on the same side of the shaft.

If the counter-weight be in the flywheel, see if it has any side motion when the engine is running, or, in other words, see if the flywheel is out of true sideways. If such is the case, it shows that the crank shaft is too weak for an engine of this kind.

Find out if the bearings give trouble from over heating, and be particular to ask for any experience in this matter. Find out if it is necesary to watch the engine at all times, or whether you may be secure in giving the engine only an occasional glance to see if it is running all right.

TWO-CYCLE MARINE ENGINES.

A single cylinder two-cycle type of marine engine mounted on a base with reversing gear, propeller and shaft is shown in Figure 130. Such outfits are made in single units of from 1½ to 7½ horsepower.

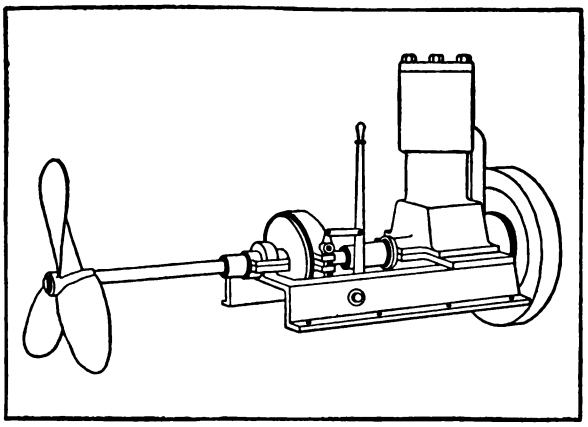


Fig. 130.

Another form of single cylinder two-cycle marine engine is shown in Figure 131. It has ball shaft and thrust bearings, variable make and break form of ignition and universal joint connection to propeller shaft.

Figure 132 shows a two-cylinder of the same type.

HANDLING MARINE ENGINE WITH REVERSE LEVER.

In handling the engine when desiring to make a stop, no matter whether equipped with reversing gear or reversing propeller, never stop the engine until the actual stopping point is reached. Many accidents are caused by operators getting excited and stopping the motor when it should have been allowed to run and depend on the reversing mechanism. When the engine has no reversing device and is dependent upon reversing the engine. always make the approach to a landing from the side.

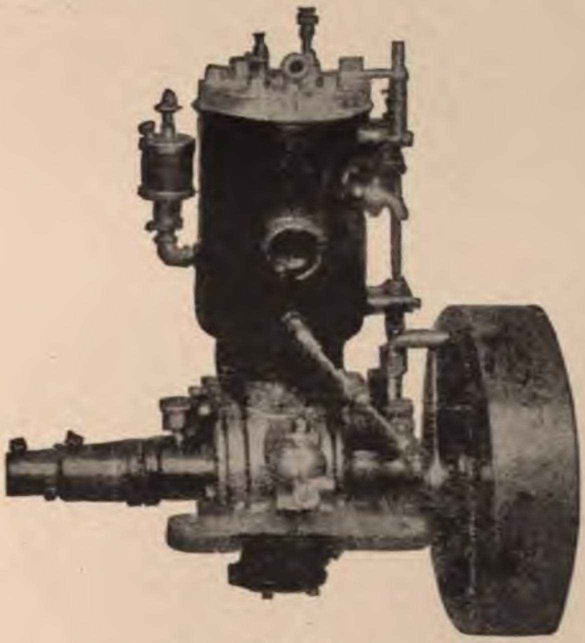


Fig. 131.
SINGLE CYLINDER MOTOR.

PROPELLERS FOR MOTOR BOATS.

The propeller wheels used on motor boats are, as a rule, smaller in diameter than employed in steam practice, the reason for this being that the gasoline engine is usually run at a higher rate of speed, and where no reversing gear is used, the engine has to start against the full load of the wheel. Of late, the manufacturers have been using wheels of larger diameter and less pitch, the effect of this being to increase the efficiency of the propeller, making the engine easier to start, decreasing

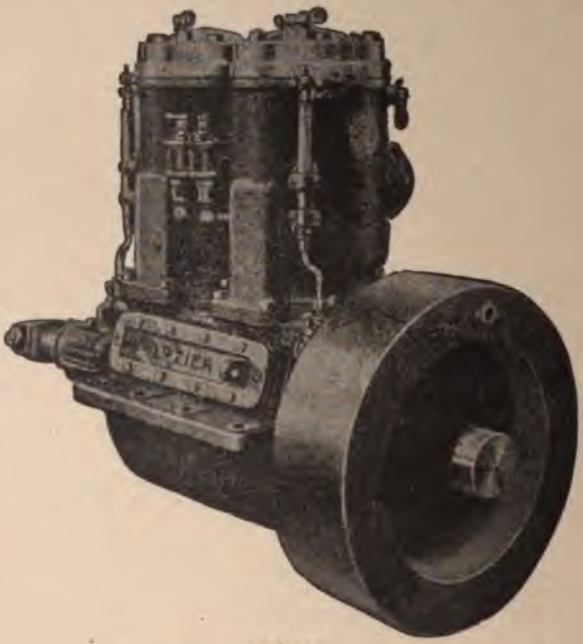


Fig. 132.
TWO CYLINDER MOTOR.

the number of revolutions somewhat, but adding to the speed of the boat. In order to avoid the use of the reversing gears inside the boat, the reversing propeller is used to a large extent. These wheels, although of many different patterns, are all practically of the same principle, the blades being turned by the movement of a sleeve surrounding the propeller shaft, which revolves with the shaft. There are no gears to intermesh or any necessity for slowing down as with the inside reversing mechanism. These propellers will reverse at full speed as they always travel in the same direction, they take hold of the water instantly.

The reversing propeller is necessarily somewhat weak structurally. It being impossible, for mechanical reasons, to design it as a perfectly true screw. It therefore lacks the efficiency of a solid propeller.

The word pitch, as applied to the propeller wheel, refers to it in the same sense as to the pitch of a screw, as the propeller in action should be a perfect screw. The pitch of the propeller designates the number of feet that it would travel in one revolution, supposing it to be a screw. If a propeller wheel is 20 inches in diameter and has 30 inches pitch, it denotes that it will travel 30 inches in each revolution. It is by this means that calculations are made on the speed of the boat. In small motor boats any estimates based on these calculations will, as a rule, prove anything but reliable, as the proportion of beam to length is in all cases excessive in comparison with larger vessels. Of course, as the pitch of the propeller wheel is decreased, a slower screw is had and consequently a more powerful one. For this reason it is becoming the practice of high speed boats to use a wheel of the least possible pitch, and in order to gain on the the travel of the screw to increase the number of the revolutions of the propeller.

The form and general design of the propeller have been so extensively experimented with, that the subject is almost worn threadbare, and it is sufficient to say that the true screw propeller will, in all probability, remain as at first the standard of excellence.

COUPLINGS AND THRUST BEARINGS.

On the opposite end of the crank shaft from the fly-wheel, is the shaft coupling and thrust bearing. The thrust bearing, which is intended to take up the thrust or push from the propeller, is sometimes made up of a number of balls fitted in a cage between the couplings and the after bearing of the engine, or in a great many cases a groove is turned in the coupling for a ball race, the opposite side being a flat, hardened steel washer. While this is a very neat and effective arrangement, it has been found from actual experience that ball-bearings in marine work are not a success. The older method, and the one still used on large marine engines, is the ring thrust, composed of a shaft with a number of collars turned on it which mesh into a set of babbitt metal rings fastened to the keel and entirely separate from the engine. The necessity of a good thrust bearing, is sadly neglected by the launch owner, as a thrust bearing of good design, if carefully looked after, will in the majority of cases not only keep the engine in much better working order and save a good deal of wear, but in many cases prevent a broken connecting rod.

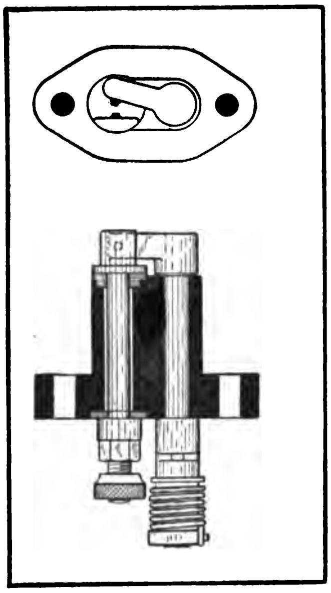


Fig. 133.

PRIMARY-SPARK PLUG.

The construction of one of the usual forms of make-and-break primary-spark plugs as used on marine engines is clearly shown in Figure 133. The upper and fixed electrode is insulated by means of mica or lava washers and is secured in place by means of a lock nut and washer. The movable electrode has a coil spring around its outer end, one end of the spring secured to the spindle of the electrode and the other to the hub of a small trigger on the extreme end of the spindle. This construction allows for any wear on the contact-points and at all times ensures a good contact between them.

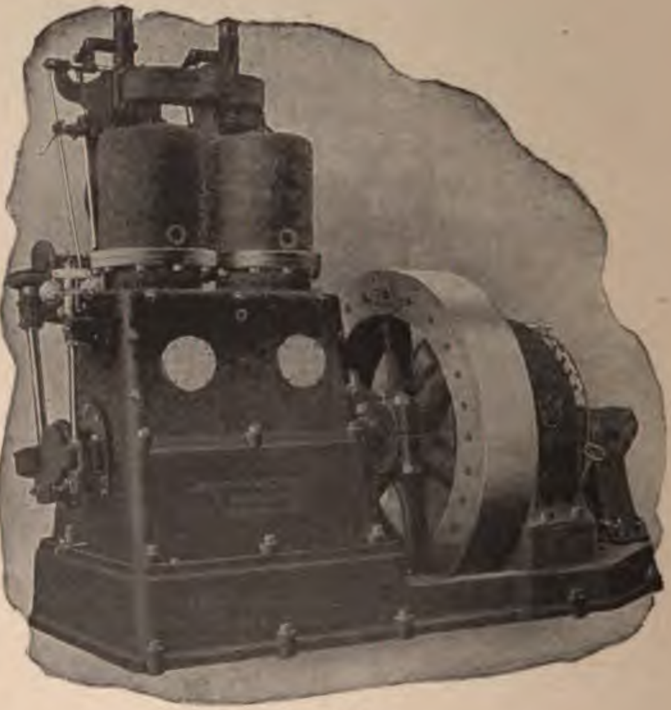


Fig. 134.

TWO-CYLINDER VERTICAL GAS ENGINE, DIRECT-CONNECTED TO GENERATOR.

CHAPTER XXXVI.

STATIONARY GAS ENGINES.

Fig. 134 shows a two cylinder vertical gas engine, direct connected to a generator, the entire outfit being mounted on sub-base, thereby insuring perfect alignment.

This type of engine is made with two, three or four cylinders, depending upon size required.

The closest regulation may be had on this type of engine, making it desirable for all electrical purposes, or for any installation, where floor space is an important item, and close regulation is required.

This engine operates on producer gas, but will operate equally as well on natural, blast furnace and illuminating gas.

The engine shown in Fig. 135 takes an explosion at every half revolution. The amount of power required determines the amount of mixture admitted. The valve mechanism is so arranged that the combustible chamber is scavenged by a charge of pure air before the mixture is admitted. This is an important feature of a successful producer gas engine.

The engine operates equally as well on natural, blast furnace and illuminating gas.

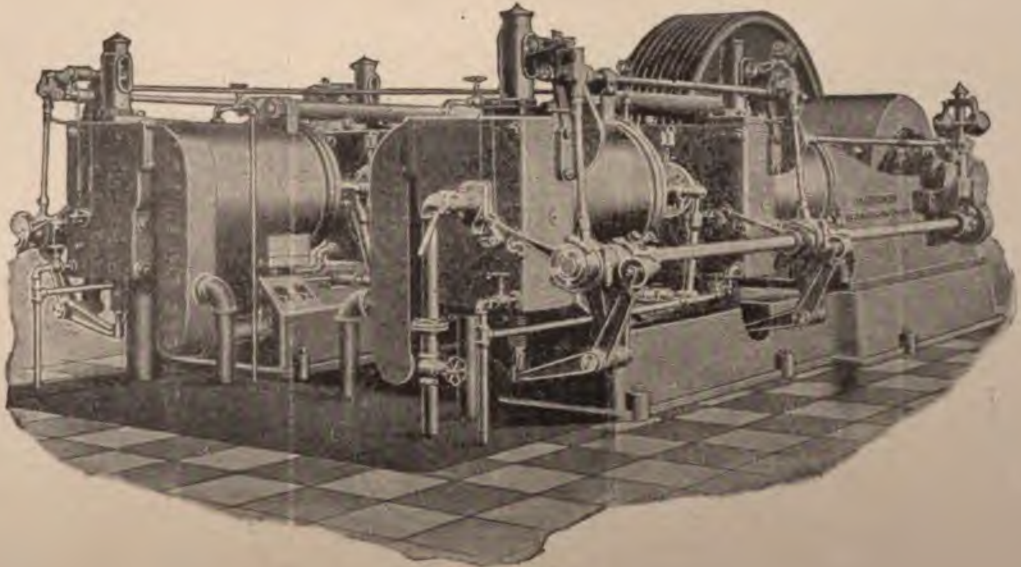


Fig. 135.

FOUR-CYLINDER HORIZONTAL GAS ENGINE.

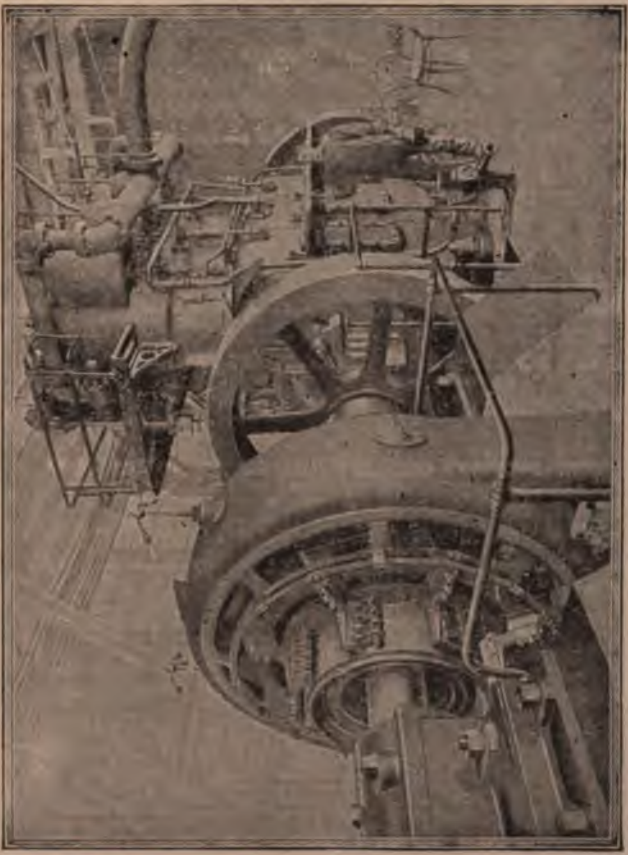


Fig. 136.
THREE-CYLINDER GAS ENGINE, DIRECT-CONNECTED TO A GENERATOR.

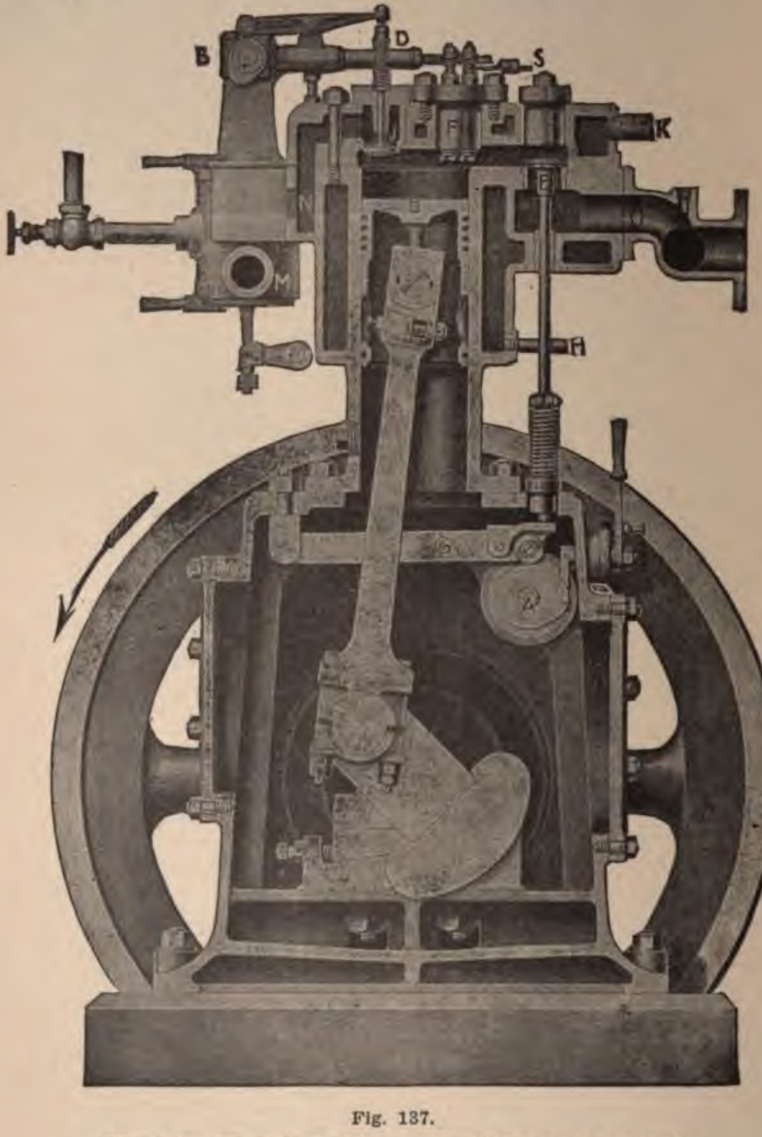


Fig. 137.
VERTICAL SECTION THROUGH FOUR-CYCLE GAS ENGINE.

CHAPTER XXXVII.

STEAM FIRE ENGINES.

The Fox Sectional Boiler, with which this fire engine is equipped, is a steam generator of the vertical water-tube type. Its design, while simple, is bold in conception, and embodies some very original ideas as to the arrangement of the tube surface, method of circulation, and constructive features generally.

The boiler has been devised primarily to meet the requirements peculiar to the fire service, although its usefulness is by no means limited to that particular duty.

In its outward form, the boiler does not differ from such as have been in universal use; the object attained in its internal arrangement, however, is a complete rejection of such features as an intimate acquaintance with the subject has shown to be objectionable.

The boiler consists primarily of a simple annular shell, heavily stay-bolted throughout, and constitutes a water-legged fire-box and steam reservoir. The shell being entirely devoid of heads, crown sheet, smoke flues or other inaccessible complications, this part of the boiler is as permanent as anything that can be devised to serve as a foundation for the support of the active steam-generating units which are attached thereto. The principal heating surface of the boiler consists of straight water tubes, manifolded in sectional form and housed within the above-described shell, the general scheme providing arrangements to make all connections readily accessible, and permitting the withdrawal from the boiler of any one or all of the several tube sections. The advantages of a boiler constructed on such lines are very apparent; the shell, being practically a permanent feature, need never be disturbed by reason of any subsequent repairs or renewals of the tube systems.

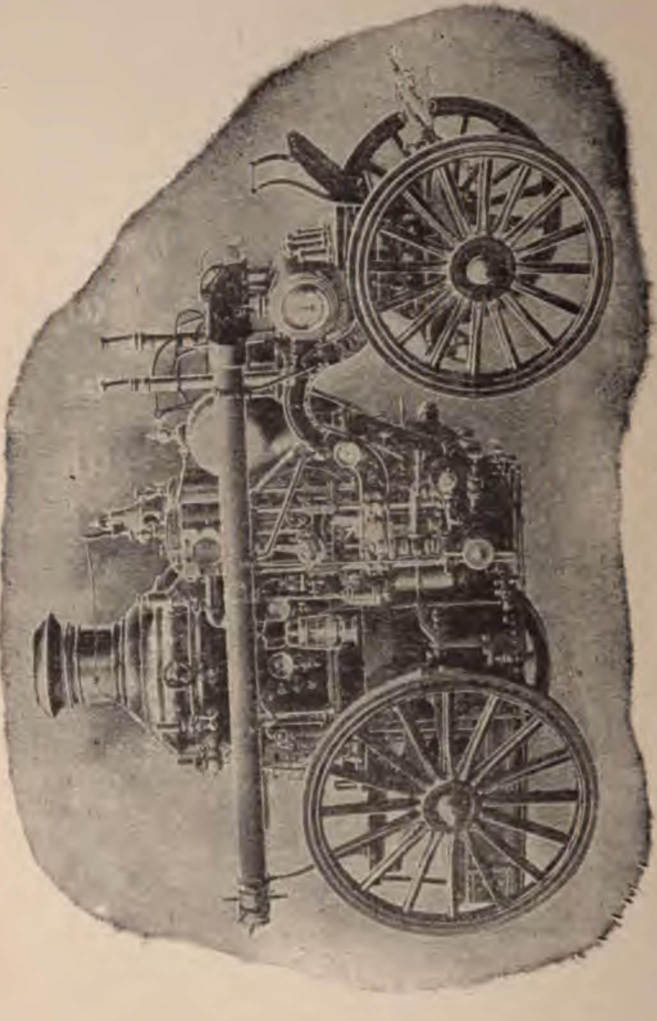


Fig. 138.
SIDE ELEVATION.

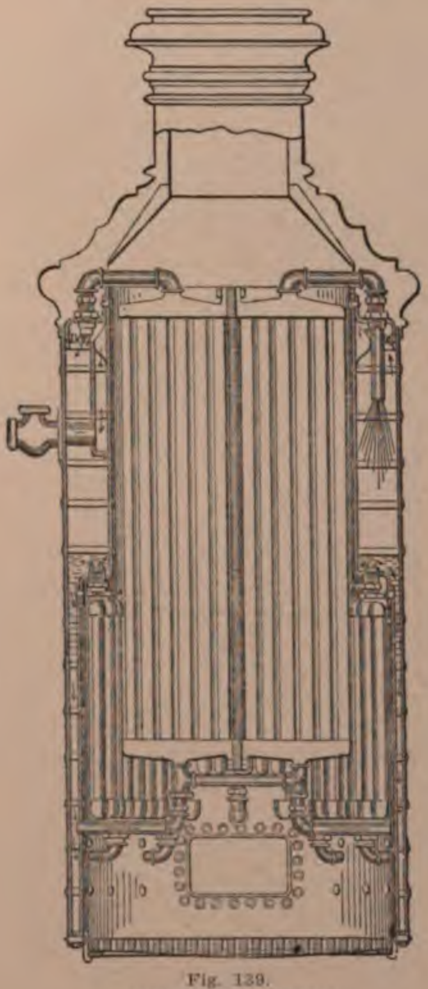


Fig. 139.
VERTICAL SECTION.

The life of both water tubes and fire tubes is generally found disproportionate to the heavier parts used in boiler construction, and experience shows conclusively that the cost of subsequent maintenance is measured directly by, and may be diminished by, the facility with which these indispensable parts may be replaced or repaired in an emergency.

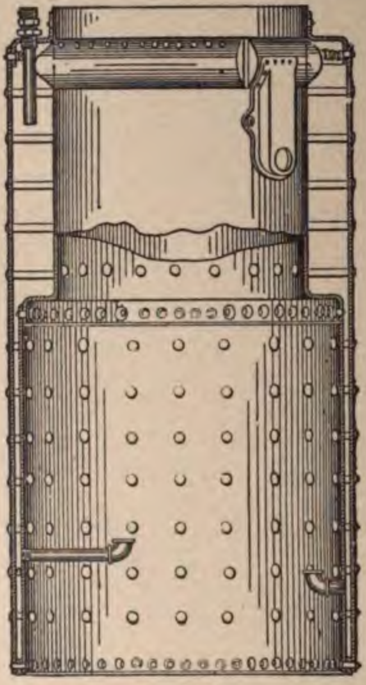


Fig. 140.

SECTIONAL VIEW OF SHELL WITH TUBES REMOVED.

In addition to fully embracing this most valuable feature in a thoroughly practical manner, continued tests of the Fox Boiler prove that this desirable advantage is secured without infringement on such other requirements as are essential to a safe, efficient and easily managed steam boiler.

Resuming the description of the boiler, it should be noted that the lower part, or water leg, of the shell is contracted for the purpose of facilitating the rapid generation of steam, and also providing the maximum grate area allowable within the limits of any given exterior diameter. At a point somewhat below the normal water line of the boiler, the inner shell is flanged inward, thereby enlarging the annular space between the inner and outer sheets for the purpose of providing a more copious reservoir.

The water line being carried in this larger part of the shell, tends to prevent the rapid fluctuation of the water level, and the increased area of its surface at this point is favorable to the disengagement of the steam.

When held at its normal point, the water line fully protects the flanged part of the inner shell; but no damage can occur, either from a willful or an accidental drawing down of the water, as the spray deflected through the nipples of the outer tubes is sufficient to protect the flange, although the actual water level is well down in the leg.

The steam in contact with the upper part of the shell is by no means dry, and experience proves that the heat absorbed at this point is sufficient to amply protect it and very materially assist in bringing the steam to a proper working pitch.

To insure a delivery of dry steam to the cylinders, a peculiar "take-off" ring is provided at the highest part of the steam reservoir, the same encircling the inside sheet of the shell. The upper edge of the ring is perforated at a distant point from the throttle, and the steam entering the ring chamber in small streams is held in close contact with the hot shell at a point closely adjacent to the upper line of rivets; the steam by this means is quite effectually dried during its passage to the throttle, and the heat thus absorbed serves as a protection to the rivets just referred to.

The principal heating surface of the boiler is contrived in the vertical water-tube sections, which comprise and will be referred to as an inner and an outer tube-system.

The outer system embraces the short manifolded sections which completely encircle the fire-box walls.

The top of each separate section is screwed and suspended from the flanged part of the shell, and the lower end is stayed by a direct connection into the leg of the fire-box. The position of the tubes in the outer system is such as to expose their surfaces to the direct action of the fire, with the least possible disturbance or hindrance to combustion.

The tubes are "staggered" in their manifolds, thereby exposing the greatest possible surface to the fire, and effectually filling out the space due to the difference in the width of the water leg and steam space of the shell.

The direct and fierce application of heat to the tubes just referred to causes a natural and active upward current therein, which in turn induces a corresponding downward tendency to the water in the leg of the fire-box, and promotes the flow into the feed pipes arranged to supply the inner system of tubes.

The inner-tube system comprises those tube sections which extend to the upper limits of the boiler, their number and arrangement being such as to completely fill the interior of the shell above the space allotted and required for the combustion of the fuel. The construction of the vertical inner-tube system is simple, and consists of the required number of manifolded sections, suitably arranged to conform to the circular space occupied, the flat inner end of each upper manifold being rigidly bolted to a heavy transverse beam, which in turn is supported in suitable pockets secured to the upper part of the shell.

The flat ends of the manifolds abutting on the beam serve to protect the same from the action of the fire, and all parts of the system are allowed perfect freedom for expansion.

The sections opposite one another on the beam are united by a right and left nipple at the bottom, and a single connection to the leg of the fire-box serves to

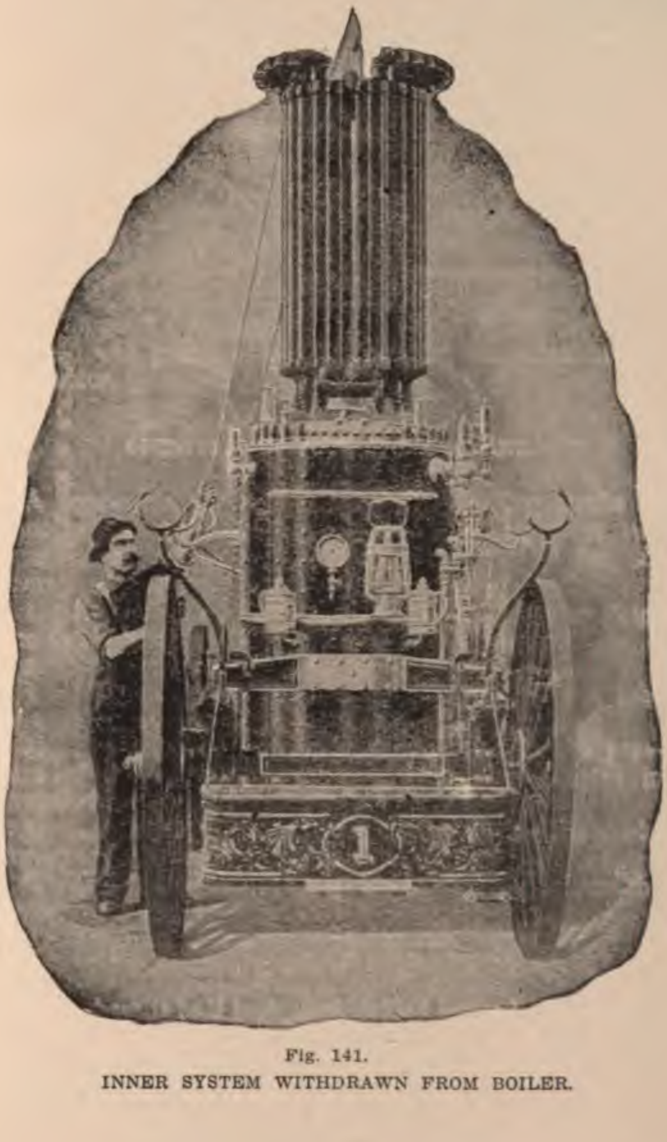


Fig. 141.
INNER SYSTEM WITHDRAWN FROM BOILER.

supply both. Suitable provision is made for properly staying the lower ends of the sections without depending on the pipe connections.

At the top of the boiler, each section has its own separate and distinct connection with the steam space, and it is possible to remove either one of the sections separately without disturbing any of the others; or the entire inner-tube system can be raised out of the boiler as a whole, after breaking the proper connections, all of which are perfectly accessible and may be handled with ordinary tools.

The current of steam and water carried over through the top connections of the inner system is sufficient to keep the tubes clear of scale; and the point of discharge and disengagement is brought down low, to prevent its mixture with the drier steam contained in the highest part of the shell.

The heating surface of the boiler is very effective. Cinders can find no lodgment, and the draft can never become impaired by accumulation of soot.

The arrangement of the tubes permits fully twenty per cent more heating surface to be placed within the range of the fire than has been customary in the older forms of boilers; as a consequence, steam is generated freely and firing made easy.

The boiler is in no way top-heavy, and the absence of a crown sheet is a further advantage too important to be overlooked in a boiler designed for portable service. The boiler can be safely operated, standing on any angle, inside the limit necessary to keep it erect; consequently, there is no danger in the shifting of the water line while running over grades or ruts, and the usual delay of leveling up is entirely avoided.

When connected to a stationary heater as is now the general practice in all fire departments, the circulative currents reach all parts of the boiler, and all of the water contained in the boiler may be kept uniformly at any temperature desirable.

The boilers are constructed by the skilled workmen of the company. The shells are of steel and have well riv-

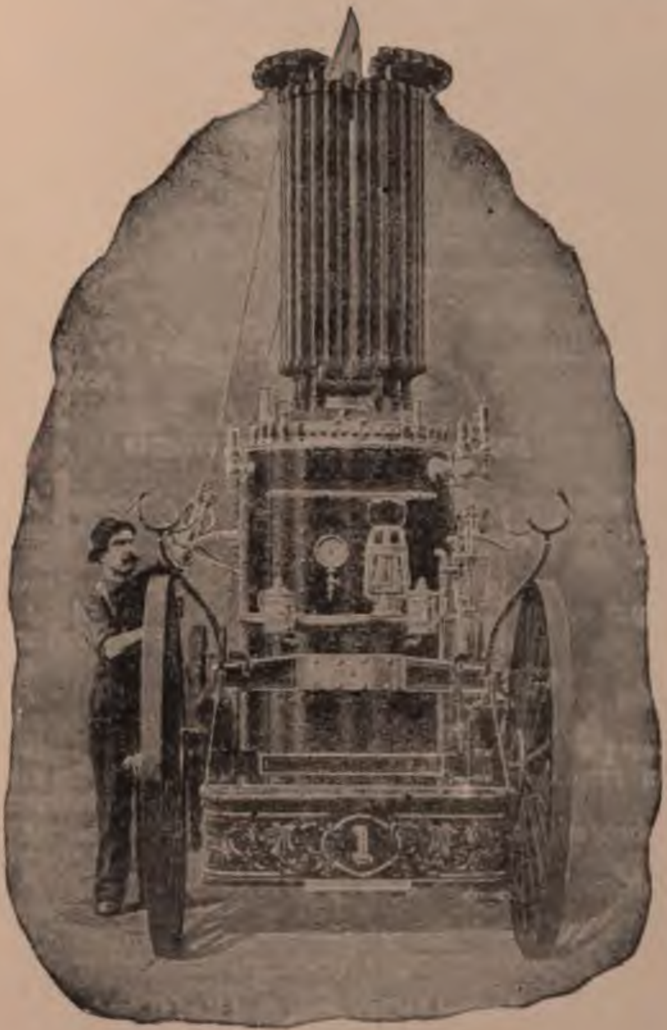


Fig. 141.
INNER SYSTEM WITHDRAWN FROM BOILER.

The value of perfect water ways, and all which that implies, has been fully recognized in the design of the

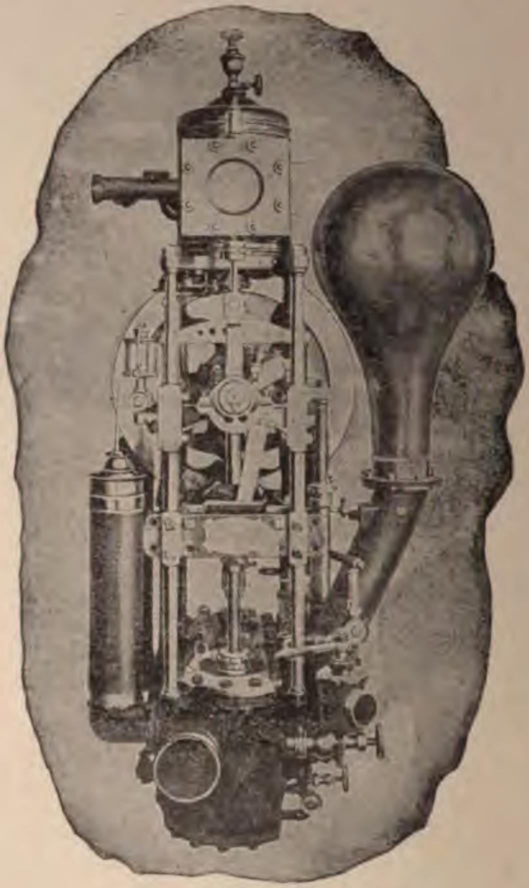


Fig. 142.

American pump, and the passages, etc., therein provided are by far the most simple and direct ever placed in a vertical piston pump.

The facilities provided for exposing the interior mechanism of the American pump permits all such parts to be readily reached for examination, or detached for renewal or repair, and in all cases this can be done with-

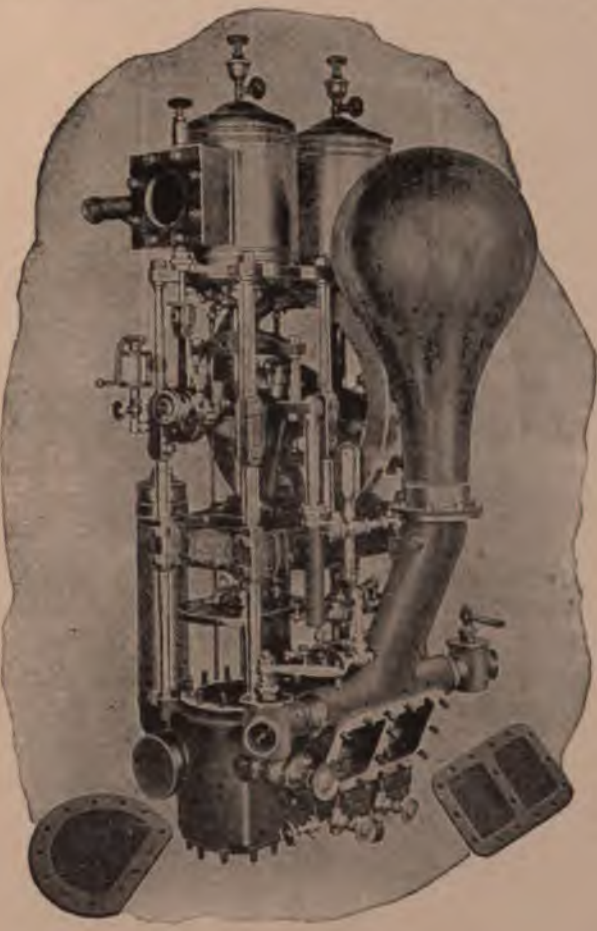


Fig. 143.

out dismounting the entire pump or greatly disturbing its exterior attachments. It will be seen, by reference to the cuts, that any of the valves can be easily and quickly examined, and also replaced, by simply removing the caps or heads that enclose the chambers.

A point of essential merit in connection with this feature of the pump is that all joints required for this purpose are made between flat surfaces planed perfectly true, as shown in Fig. 143.

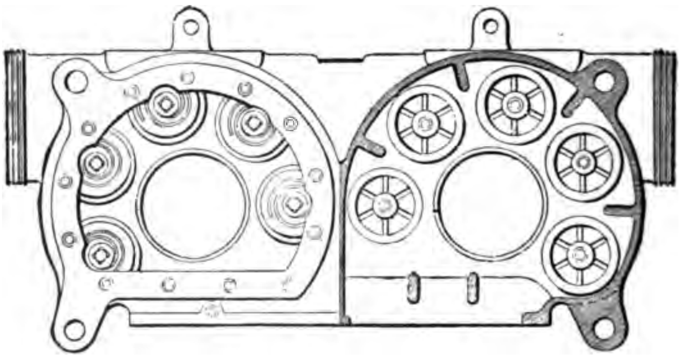


Fig. 144.

Gun metal or other suitable composition is used exclusively, and no part of the pump body is subject to wear, either by friction or corrosion. All valve seats are screwed into place, and either these or the working barrels of the pump may be readily replaced with new ones, in case the same should become worn after years of service. In the latest pumps, all stud bolts, nuts, etc., coming in contact with water are made of drawn phosphor bronze; all nipples, piping, etc., are of brass, and, as a result, the American is the only absolutely non-corrosive pump now placed on a steam fire engine.

Suction or hydrant connection may be made at either side of the engine; and in operation, the central core of the pump body is practically a continuation of the suction hose, and serves to establish a direct communication with the receiving pump valves, arranged on opposite sides of the chamber. This chamber, as shown in the sectional view, Fig. 145, thus becomes the distributing center, from which the incoming water flows to the suction valves. The current from the suction is not required to change its general direction, and but little friction is encountered by the water in its diversion through the pump valves.

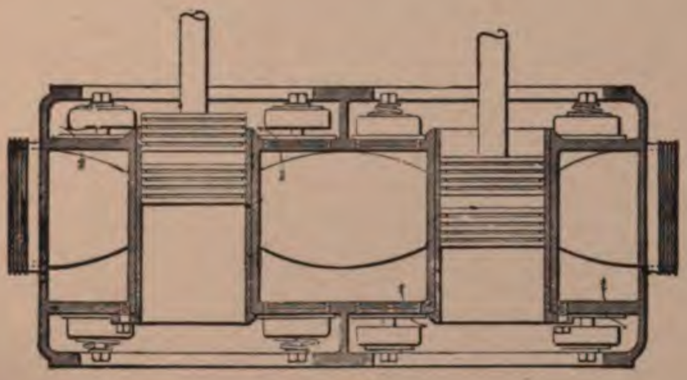


Fig 145.

The position of the suction or receiving valves, in relation to the water cylinders, continues to be a distinctive feature in the new model, and may be fully understood by reference to Fig. 144 which shows the same arranged in a cluster around the open end of the barrels. The suction valve area is large, and the proportions adopted contribute largely to the smooth running plendid efficiency of the American Pumps, under ons of speed never attempted in ordinary prac-

All valves in the pump are controlled by patent improved springs, the tension of which is at all times the same; and being made of a special phosphor bronze, the springs retain their elasticity and will not corrode.

The force chambers in opposite ends of the pumps are practically equal, and, owing to the close proximity of the valves, the clearance is reduced to the minimum. The discharging outlets are elevated above the highest point of the valve chambers, and the communicating passages are designed to prevent conflicting currents, and also to permit the pump to free itself promptly of air. The pistons adopted for the American Pump are of a new and frictionless type, and, in accordance with the usual practice of working double pumps in unison, the cranks controlling the movements of the pistons are placed at 90 degrees.

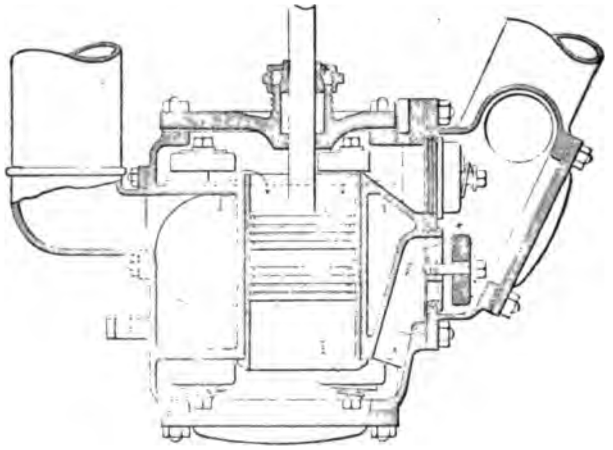


Fig. 146.

A convenient and effective arrangement of suction strainers is shown by Fig. 147.

Perforated cages are introduced into the suction chamber through the inlets on opposite sides of the pump. The ends of these cages are open, and a short sleeve, which is permanently secured within the pump, serves to support and also to establish communication from one cage to the other.

The surface of both cages is therefore available as a strainer, and any obstruction entering with the water is carried to the opposite side, to a point where it can be removed, without first detaching the suction hose.

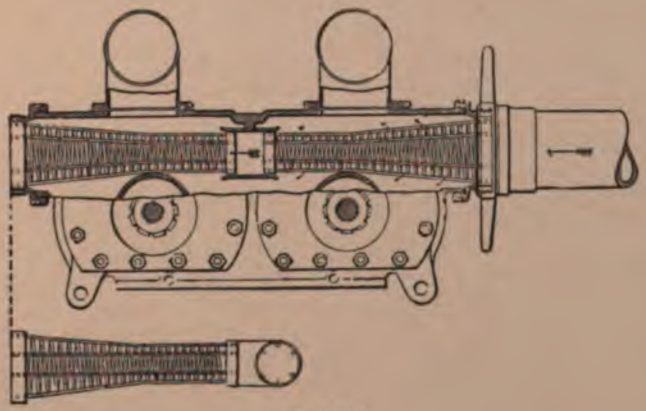


Fig. 147.

The driving mechanism supplied with the American Pump is shown by Figs. 142 and 143, which are perspective views taken from photographs. It may be noted that the design is particularly compact and well balanced, and embodies many excellent advantages found in no other type.

The pumps, steam cylinders and driving parts are built as a unit, and have no direct connection with the boiler other than the necessary stays and pipe connections, all of which are readily accessible and visible for inspection at any time.

The steam cylinders used in connection with the pump are of the ordinary slided-valve type. The valve chests are readily opened from either side of the engine for examination, and the valve rods are made from a special composition and cannot corrode. The valve movement is simple, and there is nothing connected with the steam ends that may not be readily understood at a glance. The steam pistons are of the Babbitt & Harris type, and motion is communicated to the pump piston by an arrangement both strong and direct, and also graceful in appearance. In the improved models, the pump piston rods are of solid drawn tobin bronze, and the nuts securing the pump pistons are of composition. The connecting rods are of an original design, and are longer than the usual proportion in fire-engine practice. The crank shaft is a solid steel forging, and the journal and connecting-rod bearings are extra long. The rim of the fly-wheel is balanced to lighten the weight of the reciprocating parts, and its central position on the crank shaft permits it to transmit its momentum to either side without carrying the strain through the entire length of the shaft. Placing the wheel centrally also permits the stuffing boxes and other details to be reached without stopping the engine, and adds considerably to the safety of the attendant.

Engines running over 7-inch stroke of piston are fitted with the guide shown on the engravings. The effect of this guide is the equivalent of shortening the distance between the cylinder and pump heads by more than half, and is at once the neatest and most effective way of steadying the action of the pump rod that has as yet been devised.

All bearings are special brass composition, and are more than ordinarily generous. Provision for taking up wear is made at all points requiring it.

DECIMAL EQUIVALENTS OF A FOOT IN INCHES.

Inches.	Equivalents.	Inches.	Equivalent.	Inches.	Equivalent.
1/16	.0052083	2 1/2	.2083	5 3/4	.47916
1/8	.010416	2 5/8	.21875	5 7/8	.489583
3/16	.015625	2 3/4	.22916	6	.5
1/4	.02083	2 7/8	.239583	6 1/4	.52083
5/16	.0260416	3	.25	6 1/2	.5416
3/8	.03125	3 1/8	.260416	6 3/4	.5625
7/16	.0364583	3 1/4	.27083	7	.583
1/2	.0416	3 3/8	.28125	7 1/4	.60416
9/16	.046875	3 1/2	.2916	7 1/2	.625
5/8	.052083	3 5/8	.302083	7 3/4	.64583
11/16	.0572916	3 3/4	.3125	8	.6666
3/4	.0625	3 7/8	.322916	8 1/4	.6875
13/16	.0677083	4	.3333	8 1/2	.7083
7/8	.072916	4 1/8	.34375	8 3/4	.72916
15/16	.078125	4 1/4	.35416	9	.75
1	.083	4 3/8	.364583	9 1/4	.77083
1 1/8	.09375	4 1/2	.375	9 1/2	.7916
1 1/4	.10416	4 5/8	.385416	9 3/4	.8125
1 3/8	.114583	4 3/4	.39583	10	.8333
1 1/2	.125	4 7/8	.40625	10 1/4	.85416
1 5/8	.135416	5	.416	10 1/2	.875
1 3/4	.14583	5 1/8	.427083	10 3/4	.89583
1 7/8	.15625	5 1/4	.4375	11	.916
2	.1666	5 3/8	.447916	11 1/4	.9375
2 1/8	.177083	5 1/2	.4583	11 1/2	.9583
2 1/4	.1875	5 5/8	.46875	11 3/4	.97916
2 3/8	.197916			12	1.

DECIMAL EQUIVALENTS OF AN INCH.

1/32	.03125	3/8	.375	11/16	.6875
1/16	.0625	13/32	.40625	23/32	.71875
3/32	.09375	7/16	.4375	3/4	.75
1/8	.125	15/32	.46875	25/32	.78125
5/32	.15625	1/2	.5	13/16	.8125
3/16	.1875	17/32	.53125	27/32	.84375
7/32	.21875	9/16	.5625	7/8	.875
1/4	.25	19/32	.59375	29/32	.90625
9/32	.28125	5/8	.625	15/16	.9375
5/16	.3125	21/32	.65625	31/32	.96875
11/32	.34375			1	1.

Heat. One of the remarkable effects of the application of heat to matter is, that the same amount will affect equal weights of dissimilar kinds in different degrees. Thus the amount of heat that will raise 1 pound of water from 100 degrees Fahrenheit to 200 degrees Fahrenheit, will raise 30 pounds of mercury through the same range. The amount that will raise 1 pound of water 1 degree, will raise 14 pounds of air 1 degree Fahrenheit.

The capacity of a body for heat is termed its specific heat, and may be defined as the number of units of heat necessary to raise the temperature of 1 pound of that body 1 degree Fahrenheit.

The thermal unit, or unit of heat, is the quantity of heat that will raise 1 pound of pure water 1 degree Fahrenheit, or from 39 degrees to 40 degrees Fahrenheit.

Latent heat is the quantity of heat which has disappeared from a body owing to an increase of temperature. The sensible heat is that which is sensible to the touch or measurable by the thermometer.

SPECIFIC HEAT OF DIFFERENT SUBSTANCES.

SOLIDS.	
Copper	.0951
Gold	.0324
Iron	.1138
Lead	.0314
Platinum	.0324
Silver	.0570
Tin	.0562
Zinc	.0955
Brass	.0939
Glass	.1977
Ice	.5040
Sulphur	.2020
Charcoal	.2410
Alumina	.1970
Stones, bricks, &c. about	.2200
LIQUIDS.	
Water	1.
Lead, melted	.0402
Sulphur, melted	.2840
Bismuth, melted	.0363
Tin, melted	.0637
Mercury	.0332
Alcohol	.6150
Fusel oil	.5640
Benzine	.4500
Ether	.5034

LATENT HEAT OF VARIOUS SUBSTANCES.

Substance.	Deg. Fah.	Substance.	Deg. Fah.
Alcohol	442	Lead	162
Ammonia	860	Sulphur	144
Beeswax	176	Steam	990
Ether	301	Vinegar	875
Ice	140	Zinc	493

FUSING POINTS OF THE PRINCIPAL METALS AND OTHER ELEMENTS EMPLOYED IN ALLOYS.

Substance.	Deg. Fah.	Substance.	Deg. Fah.
Aluminum	1292	Lead	626
Antimony	797	Mercury	40
Arsenic	773	Nickel	2732 to 2912
Bismuth	504	Phosphorus	111
Cadmium	608	Platinum	4712
Copper	1922	Silver	1832
Gold	2282	Sulphur	239
Iron, cast	1922 to 2192	Tellurium	716
Iron, steel	2372 to 2552	Tin	455
Iron, wrought	2732 to 2912	Zinc	773

RELATIVE HEAT-CONDUCTING POWER OF BODIES.

Substance.	Relative Conducting Power	Substance.	Relative Conducting Power
Gold	1.000	Zinc	.363
Platinum	.981	Tin	.304
Silver	.973	Lead	.108
Copper	.892	Marble	.024
Brass	.749	Porcelain	.012
Cast Iron	.562	Terra-Cotta	.011
Wrought Iron	.374		

EFFECTS OF HEAT UPON BODIES.

SUBSTANCE.	Degrees Fahrenheit.
Cast iron melts at	2754
Fine gold melts at	1983
Fine silver melts at	1850
Copper melts at	2160
Brass melts at	1900
Zinc melts at	740
Lead melts at	594
Bismuth melts at	476
Tin melts at	421
Tin and bismuth (equal parts) melt at	283
Tin 3 parts, bismuth 5, and lead 2, melt at	212
Mercury boils at	630
Linseed oil boils at	600
Alcohol boils at	174
Ether boils at	98
Mercury melts at	39

EXPANSION OF METALS BY HEAT.

In raising the temperature of bars of various metals from 32° Fahrenheit to 212° Fahrenheit, they are found to expand nearly as follows:

Metal.	Parts.	Metal.	Parts.
Platinum	1 in 1097	Copper	1 in 557
Palladium	" 1000	Gunmetal (cop. 8 tin 1)	" 550
Antimony	" 923	Brass	" 524
Cast iron	" 901	Speculum metal	" 517
Steel	" 824	Silver	" 499
Wrought iron	" 801	Tin	" 424
Bismuth	" 718	Lead	" 350
Gold	" 667	Zinc	" 336

PROPERTIES OF METALS.

	Melting Point. Degrees Fahrenheit.	Weight in Lbs. per Cubic Foot.	Weight in Lbs. per Cubic Inch.	Tensile Strength in Pounds per Square Inch.
Aluminum	1140	166.5	.0963	15000-30000
Antimony	810-1000	421.6	.2439	1050
Brass (average)	1500-1700	523.2	.3027	30000-45000
Copper	1930	552.	.3195	30000-40000
Gold (pure)	2100	1200.9	.6949	20380
Iron, cast	1900-2200	450.	.2604	20000-35000
Iron, wrought	2700-2830	480.	.2779	35000-60000
Lead	618	709.7	.4106	1000-3000
Mercury	39	846.8	.4900	
Nickel	2800	548.7	.3175	
Silver (pure)	1800	655.1	.3791	40000
Steel	2370-2685	489.6	.2834	50000-120000
Tin	475	458.3	.2652	5000
Zinc	780	436.5	.2526	3500

NOTE.—The wide variations in the tensile strength are due to the different forms and qualities of the metal tested. In the case of lead, the lowest strength is for lead cast in a mould, the highest for wire drawn after numerous workings of the metal. With steel it varies with the percentage of carbon used, which is varied according to the grade of steel required. Mercury becomes solid at 39 degrees below zero.

PROPERTIES OF METALS.

Name of Metal.	Specific Gravity.	Melting Point.		Relative Ductility.	Relative Malleability.	Relative Tenacity.
		Degrees. Fah.	Degrees. Cent.			
Aluminum	2.56	1050	565.5	6	5	9
Antimony	6.7	810	432.2	—	—	—
Bismuth	9.9	500	260.	—	—	—
Copper	8.9	2000	1093.3	5	3	2
Gold	19.5	2016	1102.2	1	1	5
Iron	7.8	2700	1482.2	4	9	1
Lead	11.4	612	322.2	9	7	8
Nickel	8.82	2700	1482.2	10	10	—
Platinum	21.5	3080	1693.3	3	6	3
Silver	10.5	1873	1022.7	2	2	4
Tin	7.3	442	227.7	8	4	7
Zinc	7.	773	411.6	7	8	6

SPECIFIC GRAVITIES AND MELTING-POINTS OF METALS.

Metals.	Specific Gravities.	Melting-points. (Centigrade.)
Antimony	6.7	432
Bismuth	9.8	268.3
Copper (cast)	8.6	1054
" (wrought)	8.8	1054
Steel	7.8	1300 to 1400
Cadmium	8.6	320.7
Iron (wrought)	7.8	1500 to 1600
Lead	11.36	326.2
Tin	7.29	232.7
Zinc	7.19	433.3
Aluminum	2.67	1045
Nickel	8.3	1450
Platinum	21.25	1775

Melting, Boiling and Freezing Points in Degrees Fahrenheit of Various Substances.

Substance.	Melts at Degrees	Substance.	Melts at Degrees
Platinum	3080	Antimony	810
Wrought-Iron	2830	Zinc	780
Nickel	2800	Lead	618
Steel	2600	Bismuth	476
Cast-Iron	2200	Tin	475
Gold (pure)	2100	Cadmium	442
Copper	1930	Sulphur	226
Gun Metal	1960	Bees-Wax	151
Brass	1900	Spermaceti	142
Silver (pure)	1800	Tallow	72
Aluminum	1140	Mercury	39

Substance.	Boils at Degrees	Substance.	Freezes at Degrees
Mercury	660	Olive Oil	36
Linseed Oil	600	Fresh Water	32
Sulphuric Acid	590	Vinegar	28
Oil of Turpentine	560	Sea Water	27½
Nitric Acid	242	Turpentine	14
Sea Water	213	Sulphuric Acid	1
Fresh Water	212		

MALLEABILITY, DUCTILITY AND TENACITY OF METALS.

Malleability.	Ductility.	Tenacity
Gold	Gold	Steel
Silver	Silver	Iron
Copper	Platinum	Copper
Tin	Iron	Platinum
Platinum	Copper	Silver
Lead	Aluminum	Gold
Zinc	Zinc	Zinc
Iron	Tin	Tin
Nickel	Lead	Lead

COMPOSITION AND MELTING POINTS OF SOFT SOLDERS.

Solder.	Tin.	Lead.	Bismuth.	Melting point Deg. Fahr.
Bismuth solder....................	3	5	3	202
" "	2	2	1	229
" "	1	1	1	254
" "	4	4	1	320
Tinsmith's coarse solder....	3	2		334
" fine solder........	2	1		340
Plumber's fine solder	1	2		441
" coarse solder......	1	3		482
Solder for soldering lead....	1	1½		
" " " tin......	1	2		
" " " pewter	2	1		

HARD SOLDERS OR BRAZING MIXTURES.

Solder.	Copper	Tin.	Zinc.	Brass	Silv r
Hard solder for copper and brass	1		1		
" " " " " "			1	5	
Harder " " " " "	2		1		
" " " " " "	3		1		
Silver Solder	8		8		1
" "				1	1
" "				1	2

PROPORTIONATE WEIGHT OF CASTINGS TO WEIGHT OF WOOD PATTERNS.

A Pattern Weighing One Pound Made of *(Less Weight of Core Prints)*	Cast Iron.	Brass.	Copper.	Bronze.	Bell Metal.	White Metal.
Pine or Fir	16	15.8	16.7	16.3	17.1	13.5
Oak	9	10.1	10.4	10.3	10.9	8.6
Beech	9.7	10.9	11.4	11.3	11.9	9.1
Linden	13.4	15.1	16.7	15.5	16.3	12.9
Pear	10.2	11.5	11.9	11.8	12.4	9.8
Birch	10.6	11.9	12.3	12.2	12.9	10.2
Alder	12.8	14.3	14.9	14.7	15.5	12.2
Mahogany	11.7	13.2	13.7	13.5	14.2	11.2
Brass	0.85	0.95	0.99	0.98	1.0	0.81

To ascertain the approximate weight of a casting from the weight of the pattern:

Multiply the weight of the pattern (less the weight of the core prints) by the number in the table corresponding to the material of which the pattern is made and the metal which is to be used for the casting. The result will be the approximate weight of the casting in pounds.

LETTER SIZES OF DRILLS.

Diameter Inches.	Decimals of 1 Inch.	Diameter Inches.	Decimals of 1 Inch.
A$\frac{15}{64}$	.234	N	.302
B	.238	O$\frac{5}{16}$	.316
C	.242	P$\frac{21}{64}$	.323
D	.246	Q	.332
E$\frac{1}{4}$	.250	R$\frac{11}{32}$	.339
F	.257	S	.348
G	.261	T$\frac{23}{64}$	.358
H$\frac{17}{64}$	.266	U	.368
I	.272	V$\frac{3}{8}$	.377
J	.277	W$\frac{25}{64}$	.386
K$\frac{9}{32}$	.281	X	.397
L	.290	Y$\frac{13}{32}$	.404
M$\frac{19}{64}$	.295	Z	.413

SIZES OF TAP DRILLS.

Tap Diameter.	Threads per Inch.	Drill for V Thread.	Drill for U. S. Standard.	Drill for Whitworth.
$\frac{1}{4}$	16, 18, 20	$\frac{5}{32}$ $\frac{5}{32}$ $\frac{11}{64}$	3-16	3-16
$\frac{9}{32}$	16, 18, 20	$\frac{3}{16}$ $\frac{13}{64}$ $\frac{13}{64}$		
$\frac{5}{16}$	16, 18	$\frac{7}{32}$ $\frac{15}{64}$	1-4	15-64
$\frac{11}{32}$	16, 18	$\frac{1}{4}$ $\frac{17}{64}$		
$\frac{3}{8}$	14, 16, 18	$\frac{1}{4}$ $\frac{9}{32}$ $\frac{9}{32}$	9-32	9-32
$\frac{13}{32}$	14, 16, 18	$\frac{19}{64}$ $\frac{21}{64}$ $\frac{21}{64}$		
$\frac{7}{16}$	14, 16	$\frac{21}{64}$ $\frac{11}{32}$	11-32	11-32
$\frac{15}{32}$	14, 16	$\frac{23}{64}$ $\frac{3}{8}$		
$\frac{1}{2}$	12, 13, 14	$\frac{3}{8}$ $\frac{25}{64}$ $\frac{25}{64}$	13-32	3-8
$\frac{9}{16}$	12, 14	$\frac{7}{16}$ $\frac{29}{64}$	7-16	
$\frac{5}{8}$	10, 11, 12	$\frac{15}{32}$ $\frac{1}{2}$ $\frac{1}{2}$	1-2	1-2
$\frac{11}{16}$	11, 12	$\frac{9}{16}$ $\frac{9}{16}$		
$\frac{3}{4}$	10, 11, 12	$\frac{19}{32}$ $\frac{5}{8}$ $\frac{5}{8}$	5-8	5-8
$\frac{13}{16}$	10	$\frac{21}{32}$		
$\frac{7}{8}$	9, 10	$\frac{45}{64}$ $\frac{23}{32}$	23-32	23-32
$\frac{15}{16}$	9	$\frac{49}{64}$		
1	8	$\frac{13}{16}$	27-32	27-32

WEIGHT OF SHEET IRON AND STEEL PER SQUARE FOOT.

Thickness by Birmingham Gauge.				Thickness by American (Brown & Sharpe's) Gauge.			
No. of Gauge.	Thickness in Inches.	Weight in Pounds.		No. of Gauge.	Thickness in Inches.	Weight in Pounds.	
		Iron.	Steel.			Iron	Steel.
0000	.454	18.16	18.52	0000	.46	18.40	18.77
000	.425	17.00	17.34	000	.4096	16.38	16.71
00	.38	15.20	15.30	00	.3648	14.59	14.88
0	.34	13.60	13.87	0	.3249	13.00	13.26
1	.3	12.00	12.24	1	.2893	11.57	11.80
2	.284	11.36	11.59	2	.2576	10.30	10.51
3	.259	10.36	10.57	3	.2294	9.18	9.36
4	.238	9.52	9.71	4	2043	8.17	8.34
5	.22	8.80	8.98	5	.1819	7.28	7.42
6	.203	8.12	8.28	6	.1620	6.48	6.61
7	.18	7.20	7.34	7	.1443	5.77	5.89
8	.165	6.60	6.73	8	.1285	5.14	5.24
9	.148	5.92	6.04	9	.1144	4.58	4.67
10	.134	5.36	5.47	10	.1019	4.08	4.16
11	.12	4.80	4.90	11	.0907	3.63	3.70
12	.109	4.36	4.45	12	.0808	3.23	3.30
13	.095	3.80	3.88	13	.0720	2.88	2.94
14	.083	3.32	3.39	14	.0641	2.56	2.62
15	.072	2.88	2.94	15	.0571	2.28	2.33
16	.065	2.60	2.65	16	.0508	2.03	2.07
17	.058	2.32	2.37	17	.0453	1.81	1.85
18	.049	1.96	2.00	18	.0403	1.61	1.64
19	.042	1.68	1.71	19	.0359	1.44	1.46
20	.035	1.40	1.43	20	.0320	1.28	1.31

CONTINUED—WEIGHT OF SHEET IRON AND STEEL PER SQUARE FOOT.

Thickness by Birmingham Gauge.				Thickness by American (Brown and Sharpe's) Gauge.			
No. of Gauge.	Thickness in Inches.	Weight in Pounds.		No. of Gauge.	Thickness in Inches.	Weight in Pounds.	
		Iron.	Steel.			Iron.	Steel.
21	.032	1.28	1.31	21	.0285	1.14	1.16
22	.028	1.12	1.14	22	.0253	1.01	1.03
23	.025	1.00	1.02	23	.0226	.904	.922
24	.022	.88	.898	24	.0201	.804	.820
25	.02	.80	.816	25	.0179	.716	.730
26	.018	.72	.734	26	.0159	.636	.649
27	.016	.64	.653	27	.0142	.568	.579
28	.014	.56	.571	28	.0126	.504	.514
29	.013	.52	.530	29	.0113	.452	.461
30	.012	.48	.490	30	.0100	.400	.408
31	.01	.40	.408	31	.0089	.356	.363
32	.009	.36	.367	32	.0080	.320	.326
33	.008	.32	.326	33	.0071	.284	.290
34	.007	.28	.286	34	.0063	.252	.257
35	.005	.20	.204	35	.0056	.224	.228

	IRON.	STEEL.
Specific gravity.	7.7	7.854
Weight per cubic foot,	480	489.6
Weight per cubic inch,	.2778	.2833

As there are many gauges in use differing from each other orders for sheets should always state the weight per square foot, or the thickness in thousands of an inch.

WIRE GAUGES IN USE IN THE UNITED STATES.

Number of Wire Gauge.	American or Brown & Sharpe.	Birmingham or Stubs' Wire.	Washburn & Moen Mfg. Co., Worcester, Mass.	Imperial Wire Gauge.	Stubs' Steel Wire.	U. S. Standard for Plate.	Number of Wire Gauge.
000000				.464		.46875	000000
00000				.432		.4375	00000
0000	.46	.454	.3938	.400		.40625	0000
000	.40964	.425	.3625	.372		.375	000
00	.3648	.38	.3310	.348		.34375	00
0	.32486	.34	.3065	.324		.3125	0
1	.2893	.3	.2830	.300	.227	.28125	1
2	.25763	.284	.2625	.276	.219	.265625	2
3	.22942	.259	.2437	.252	.212	.25	3
4	.20431	.238	.2253	.232	.207	.234375	4
5	.18194	.22	.2070	.212	.204	.21875	5
6	.16202	.203	.1920	.192	.201	.203125	6
7	.14428	.18	.1770	.176	.199	.1875	7
8	.12849	.165	.1620	.160	.197	.171875	8
9	.11443	.148	.1483	.144	.194	.15625	9
10	.10189	.134	.1350	.128	.191	.140625	10
11	.090742	.12	.1205	.116	.188	.125	11
12	.080808	.109	.1055	.104	.185	.109375	12
13	.071961	.095	.0915	.092	.182	.09375	13
14	.064084	.083	.0800	.080	.180	.078125	14
15	.057068	.072	.0720	.072	.178	.0703125	15
16	.05082	.065	.0625	.064	.175	.0625	16
17	.045257	.058	.0540	.056	.172	.05625	17

WIRE GAUGES IN USE IN THE UNITED STATES. (CONT.)

Number of Wire Gauge.	American or Brown & Sharpe.	Birmingham or Stubs' Wire.	Washburn & Moen Mfg. Co., Worcester, Mass.	Imperial Wire Gauge.	Stubs' Steel Wire.	U. S. Standard for Plate.	Number of Wire Gauge.
18	.040303	.049	.0475	.048	.168	.05	18
19	.03589	.042	.0410	.040	.164	.04375	19
20	.031961	.035	.0348	.036	.161	.0375	20
21	.028462	.032	.03175	.032	.157	.034375	21
22	.025347	.028	.0286	.028	.155	.03125	22
23	.022571	.025	.0258	.024	.153	.028125	23
24	.0201	.022	.0230	.022	.151	.025	24
25	.0179	.02	.0204	.020	.148	.021875	25
26	.01594	.018	.0181	.018	.146	.01875	26
27	.014195	.016	.0173	.0164	.143	.0171875	27
28	.012641	.014	.0162	.0149	.139	.015625	28
29	.011257	.013	.0150	.0136	.134	.0140625	29
30	.010025	.012	.0140	.0124	.127	.0125	30
31	.008928	.01	.0132	.0116	.120	.0109375	31
32	.00795	.009	.0128	.0108	.115	.01015625	32
33	.00708	.008	.0118	.0100	.112	.009375	33
34	.006304	.007	.0104	.0092	.110	.00859375	34
35	.005614	.005	.0095	.0084	.108	.0078125	35
36	.005	.004	.0090	.0076	.106	.00703125	36
37	.004453			.0068	.103	.006640625	37
38	.003965			.0060	.101	.00625	38
39	.003531			.0052	.099		39
40	.003144			.0048	.097		40

WEIGHT PER FOOT OF FLAT BAR STEEL.
Steel weighing 490 pounds per square foot.

Thickness in Inches	WIDTH IN INCHES.									
	1	1 1-4	1 1-2	1 3-4	2	2 1-4	2 1-2	3	3 1-2	4
3-16	.638	.797	.957	1.11	1.28	1.44	1.59	1.91	2.23	2.55
1-4	.850	1.06	1.28	1.49	1.70	1.91	2.12	2.55	2.98	3.40
5-16	1.06	1.33	1.59	1.86	2.12	2.39	2.65	3.19	3.72	4.25
3-8	1.28	1.59	1.92	2.23	2.55	2.87	3.19	3.83	4.47	5.10
7-16	1.49	1.86	2.23	2.60	2.98	3.35	3.73	4.46	5.20	5.95
1-2	1.70	2.12	2.55	2.98	3.40	3.83	4.25	5.10	5.95	6.80
9-16	1.92	2.39	2.87	3.35	3.83	4.30	4.78	5.74	6.70	7.65
5-8	2.12	2.65	3.19	3.72	4.25	4.78	5.31	6.38	7.44	8.50
11-16	2.34	2.92	3.51	4.09	4.67	5.26	5.84	7.02	8.18	9.35
3-4	2.55	3.19	3.83	4.47	5.10	5.75	6.38	7.65	8.93	10.20
13-16	2.76	3.45	4.14	4.84	5.53	6.21	6.90	8.29	9.67	11.05
7-8	2.98	3.72	4.47	5.20	5.95	6.69	7.44	8.93	10.41	11.90
15-16	3.19	3.99	4.78	5.58	6.38	7.18	7.97	9.57	11.16	12.75
1	3.40	4.25	5.10	5.95	6.80	7.65	8.50	10.20	11.90	13.60
1 1-16	3.61	4.52	5.42	6.32	7.22	8.13	9.03	10.84	12.15	14.45
1 1-8	3.83	4.78	5.74	6.70	7.65	8.61	9.57	11.48	13.39	15.30
1 3-16	4.04	5.05	6.06	7.07	8.08	9.09	10.10	12.12	14.13	16.15
1 1-4	4.25	5.31	6.38	7.44	8.50	9.57	10.63	12.75	14.87	17.00
1 5-16	4.46	5.58	6.69	7.81	8.93	10.04	11.16	13.39	15.62	17.85
1 3-8	4.67	5.84	7.02	8.18	9.35	10.52	11.69	14.03	16.36	18.70
1 7-16	4.89	6.11	7.34	8.56	9.78	11.00	12.22	14.66	17.10	19.55
1 1-2	5.10	6.38	7.65	8.93	10.20	11.48	12.75	15.30	17.85	20.40
1 9-16	5.32	6.64	7.97	9.30	10.63	11.65	13.28	15.94	18.60	21.25
1 5-8	5.52	6.90	8.29	9.67	11.05	12.43	13.81	16.58	19.34	22.10
1 11-16	5.74	7.17	8.61	10.04	11.47	12.91	14.34	17.22	20.08	22.95
1 3-4	5.95	7.44	8.93	10.42	11.90	13.40	14.88	17.85	20.83	23.80
1 13-16	6.16	7.70	9.24	10.79	12.33	13.86	15.40	18.49	21.57	24.65
1 7-8	6.38	7.97	9.57	11.15	12.75	14.34	15.94	19.13	22.31	25.50
1 15-16	6.59	8.24	9.88	11.53	13.18	14.83	16.47	19.77	23.06	26.35
2	6.80	8.50	10.20	11.90	13.60	15.30	17.00	20.40	23.80	27.20

WEIGHT PER FOOT OF FLAT BAR IRON.

Thickness.	WIDTH IN INCHES.									
	1	1¼	1½	1¾	2	2¼	2½	3	3½	4
⅛	.42	.53	.63	.74	.84	.95	1.05	1.26	1.47	1.68
¼	.84	1.05	1.26	1.47	1.68	1.90	2.11	2.53	2.95	3.37
⅜	1.26	1.58	1.90	2.21	2.53	2.84	3.16	3.79	4.42	5.05
½	1.68	2.11	2.53	2.95	3.37	3.79	4.21	5.05	5.89	6.74
⅝	2.11	2.63	3.16	3.68	4.21	4.74	5.26	6.32	7.37	8.42
¾	2.53	3.16	3.79	4.42	5.05	5.68	6.32	7.58	8.84	10.10
⅞	2.95	3.68	4.42	5.16	5.89	6.83	7.37	8.84	10.32	11.79
1	3.37	4.21	5.05	5.89	6.74	7.58	8.42	10.10	11.79	13.47

Plate iron weighs 40 pounds per square foot, 1 inch thick. Hence, a square foot weighs 10 pounds if ½ inch thick, 5 pounds if ⅛ inch thick, etc.

To find the weight of round iron, per square foot in length: Square the diameter, expressed in quarter inches and divide by 6.

Thus, a 1¼ inch rod weighs 5 × 5 = 25, 25 ÷ 6 = 4⅙ pounds per foot.

To find the weight of square or flat iron, per yard in length: Multiply the area of the cross section by 10.

Thus, a bar 2 by ⅜ has an area of ¾ of a square inch, and consequently weighs ¾ × 10 = 7½ pounds per yard.

To find the tensile strength of round iron: Square the diameter, expressed in quarters of an inch, the result will be its approximate strength in tons.

Thus, a rod 1 quarter inch in diameter will sustain 1 ton; 2 quarters, 4 tons; 3 quarters 9 tons; 4 quarters, or 1 inch, 16 tons.

If the rod is square, and of the same diameter as the round bar, it will carry about 25 per cent more, hence, a bar 1 inch square will sustain about 20 tons.

SIZE AND WEIGHT OF HOT PRESSED HEXAGON NUTS

UNITED STATES STANDARD SIZES.

Weights and sizes are for unfinished Nuts.

Width over Flats.	Thickness in Incnes.	Size of Hole.		Size of Bolt.	Weight of 100 Nuts.	Number of Nuts in 100 Lbs.
1-2	1-4	0.185	$\frac{3}{16}$ scant.	$\frac{1}{4}$	1.8	7615
19-32	5-16	0.240	$\frac{1}{4}$ “	$\frac{5}{16}$	1.9	5200
11-16	3-8	0.294	$\frac{19}{64}$ “	$\frac{3}{8}$	3.3	3000
25-32	7-16	0.344	$\frac{11}{32}$	$\frac{7}{16}$	5.0	2000
7-8	1-2	0.400	$\frac{13}{32}$ scant.	$\frac{1}{2}$	7.0	1430
31-32	9-16	0.454	$\frac{29}{64}$	$\frac{9}{16}$	9.1	1100
1 1-16	5-8	0.507	$\frac{1}{2}$ full.	$\frac{5}{8}$	13.5	740
1 1-4	3-4	0.620	$\frac{5}{8}$ scant.	$\frac{3}{4}$	22.2	450
1 7-16	7-8	0.731	$\frac{47}{64}$ scant.	$\frac{7}{8}$	32.4	309
1 5-8	1	0.837	$\frac{27}{32}$ “	1	46.3	216
1 13-16	1 1-8	0.940	$\frac{15}{16}$ full.	$1\frac{1}{8}$	67.6	148
2	1 1-4	1.065	$1\frac{1}{16}$ “	$1\frac{1}{4}$	90.1	111
2 3-16	1 3-8	1.160	$1\frac{5}{32}$ full.	$1\frac{3}{8}$	117.5	85
2 3-8	1 1-2	1.284	$1\frac{9}{32}$ “	$1\frac{1}{2}$	147.1	68
2 9-16	1 5-8	1.389	$1\frac{25}{64}$ scant.	$1\frac{5}{8}$	178.6	56
2 3-4	1 3-4	1.491	$1\frac{1}{2}$ “	$1\frac{3}{4}$	250.0	40
2 15-16	1 7-8	1.616	$1\frac{5}{8}$ scant.	$1\frac{7}{8}$	285.7	35
3 1-8	2	1.712	$1\frac{23}{32}$ “	2	344.8	29
3 5-16	2 1-8	1.836	$1\frac{27}{32}$ “	$2\frac{1}{8}$	384.6	26
3 1-2	2 1-4	1.962	$1\frac{31}{32}$ “	$2\frac{1}{4}$	434.8	23

SIZE AND WEIGHT OF HOT PRESSED SQUARE NUTS

UNITED STATES STANDARD SIZES.

Weights and sizes are for unfinished Nuts.

Width.	Thickness in Inches,	Size of Hole.		Size of Bolt.	Weight of 100 Nuts.	Number of Nuts in 100 Lbs.
1-2	1-4	0.185	3/16 scant.	1/4	1.4	7270
19-32	5-16	0.240	1/4 "	5/16	2.2	4700
11-16	3-8	0.294	19/64 "	3/8	4.3	2330
25-32	7-16	0.344	11/32	7/16	6.1	1630
7-8	1-2	0.400	13/32 scant.	1/2	9.0	1120
31-32	9-16	0.454	29/64	9/16	11.2	890
1 1-16	5-8	0.507	1/2 full.	5/8	15.6	640
1 1-4	3-4	0.620	5/8 scant.	3/4	26.3	380
1 7-16	7-8	0.731	47/64 scant.	7/8	35.7	280
1 5-8	1	0.837	27/32 "	1	58.8	170
1 13-16	1 1-8	0.940	15/16 full.	1 1/8	76.9	130
2	1 1-4	1.065	1 1/16 "	1 1/4	104.2	96
2 3-16	1 3-8	1.160	1 5/32 full.	1 3/8	142.8	70
2 3-8	1 1-2	1.284	1 9/32 "	1 1/2	172.4	58
2 9-16	1 5-8	1.389	1 25/64 scant.	1 5/8	227.3	44
2 3-4	1 3-4	1.491	1 1/2 "	1 3/4	294.1	34
2 15-16	1 7-8	1.616	1 5/8 scant.	1 7/8	370.4	27
3 1-8	2	1.712	1 23/32 "	2	416.7	24
3 5-16	2 1-8	1.836	1 27/32 "	2 1/8	500.0	20
3 1-2	2 1-4	1.962	1 31/32 "	2 1/4	588.2	17

WEIGHT AND AREA OF SQUARE AND ROUND STEEL, AND THE CIRCUMFERENCE OF ROUND BARS.

Steel weighing 490 pounds per cubic foot.

Thickness or Diameter in Inches,	Weight of Square Bar 1 ft. long.	Weight of Round Bar 1 ft. long.	Area of Square Bar in Square Inches.	Area of Round Bar in Square Inches.	Circumference of Round Bar in Inches.
3-16	.120	.094	.0352	.0276	.5890
1-4	.213	.167	.0625	.0491	.7854
5-16	.332	.261	.0977	.0767	.9817
3-8	.478	.375	.1406	.1104	1.1781
7-16	.651	.511	.1914	.1503	1.3744
1-2	.851	668	.2500	.1963	1.5708
9-16	1.076	.845	.3164	.2485	1.7671
5-8	1.329	1.044	.3906	.3068	1.9635
11-16	1.608	1.263	.4727	.3712	2.1598
3-4	1.914	1.503	.5625	.4418	2.3562
13-16	2.246	1.764	.6602	.5185	2.5525
7-8	2.605	2.046	.7656	.6013	2.7489
15-16	2.990	2.348	.8789	.6903	2.9452
1	3.402	2.672	1.0000	.7854	3.1416
1-16	3.841	3.017	1.1289	.8866	3.3379
1-8	4.306	3.382	1.2656	.9940	3.5343
3-16	4.798	3.768	1.4102	1.1075	3.7306
1-4	5.316	4.175	1.5625	1.2272	3.9270
5-16	5.861	4.603	1.7227	1.3530	4.1233
3-8	6.432	5.052	1.8906	1.4849	4.3197
7-16	7.030	5.521	2.0664	1.6230	4.5160
1-2	7.655	6.012	2.2500	1.7671	4.7124
9-16	8.306	6.524	2.4414	1.9175	4.9087
5-8	8.984	7.056	2.6406	2.0739	5.1051
11-16	9.688	7.609	2.8477	2.2365	5.3014
3-4	10.419	8.183	3.0625	2.4053	5.4978
13-16	11.177	8.778	3.2852	2.5802	5.6941
7-8	11.961	9.394	3.5156	2.7612	5.8905
15-16	12.772	10.031	3.7539	2.9483	6.0868

Weight and Area of Square and Round Steel, and the Circumference of Round Bars.

Steel weighing 490 pounds per cubic foot.

Thickness or Diameter in Inches.	Weight of Square Bar 1 ft. long.	Weight of Round Bar 1 ft. long.	Area of Square Bar in Square Inches.	Area of Round Bar in Square Inches.	Circumference of Round Bar in Inches.
2	13.61	10.69	4.0000	3.1416	6.2832
1-16	14.47	11.36	4.2539	3.3410	6.4795
1-8	15.36	12.06	4.5136	3.5466	6.6759
3-16	16.28	12.79	4.7852	3.7583	6.8722
1-4	17.22	13.52	5.0625	3.9651	7.0686
5-16	18.19	14.02	5.3477	4.2000	7.2649
3-8	19.19	15.07	5.6406	4.4301	7.4613
7-16	20.21	15.87	5.9414	4.6664	7.6576
1-2	21.26	16.70	6.2500	4.9087	7.8540
9-16	22.34	17.55	6.5664	5.1572	8.0503
5-8	23.44	18.41	6.8906	5.4119	8.2467
11-16	24.57	19.30	7.2227	5.6727	8.4430
3-4	25.73	20.21	7.5625	5.9396	8.6394
13-16	26.91	21.14	7.9102	6.2126	8.8357
7-8	28.12	22.09	8.2656	6.4918	9.0321
15-16	29.36	23.06	8.6289	6.7771	9.2284
3	30.62	24.05	9.0000	7.0686	9.4248
1-16	31.91	25.06	9.3789	7.3662	9.6211
1-8	33.23	26.10	9.7656	7.6699	9.8175
3-16	34.57	27.15	10.160	7.9798	10.014
1-4	35.94	28.23	10.563	8.2958	10.210
5-16	37.33	29.32	10.973	8.6179	10.407
3-8	38.75	30.43	11.391	8.9462	10.603
7-16	40.20	31.57	11.816	9.2806	10.799
1-2	41.68	32.74	12.250	9.6211	10.996
9-16	43.17	33.91	12.691	9.9678	11.192
5-8	44.71	35.12	13.141	10.321	11.388
11-16	46.26	36.33	13.598	10.680	11.585
3-4	47.84	37.57	14.063	11.045	11.781
13-16	49.45	38.84	14.535	11.416	11.977
7-8	51.09	40.13	15.016	11.793	12.174
15-16	52.75	41.43	15.504	12.177	12.370
4	54.45	42.77	16.00	12.566	12.566

Dimensions of Wrought-Iron Pipe.

Nominal Inside Diameter.	Actual Outside Diameter in Inches.	Actual Inside Diameter in Inches.	Thickness of Metal in Inches.	Threads per Inch.	Length of Full Thread in Inches.
1/8	.405	.270	.068	27	.19
1/4	.540	.364	.085	18	.29
3/8	.675	.493	.091	18	.30
1/2	.840	.622	.109	14	.39
3/4	1.050	.824	.113	14	.40
1	1.315	1.048	.134	11½	.51
1¼	1.660	1.380	.140	11½	.54
1½	1.900	1.610	.145	11½	.55
2	2.375	2.067	.154	11½	.58
2½	2.875	2.468	.204	8	.89
3	3.500	3.067	.217	8	.95
3½	4.000	3.548	.226	8	1.00
4	4.500	4.026	.237	8	1.05
4½	5.000	4.508	.246	8	1.10
5	5.563	5.045	.259	8	1.16
6	6.625	6.065	.280	8	1.26
7	7.625	7.023	.301	8	1.36
8	8.625	7.981	.322	8	1.46
9	9.625	8.937	.344	8	1.57
10	10.750	10.018	.366	8	1.68
11	11.75	11.000	.375	8	1.78
12	12.75	12.000	.375	8	1.88
13	14.	13.25	.375	8	2.09
14	15.	14.25	.375	8	2.10
15	16.	15.25	.375	8	2.20

Taper of the thread is ¾ inch to one foot.

Pipe from ⅛ inch to 1 inch inclusive is butt welded and tested to 300 pounds per square inch.

Pipe 1¼ inch and larger is lap welded and tested to 500 pounds per square inch.

Weight of Twelve Inches Square of Various Metals.

Thickness.	Wrought Iron.	Cast Iron.	Steel.	Gun Metal.	Brass.	Copper.	Tin.	Zinc.	Lead.
1/16	2.50	2.34	2.56	2.75	2.69	2.87	2.37	2.25	3.68
1/8	5.00	4.69	5.12	5.50	5.38	5.75	4.75	4.50	7.37
3/16	7.50	7.03	7.68	8.25	8.07	8.62	7.12	6.75	11.05
1/4	10.00	9.38	10.25	11.00	10.75	11.50	9.50	9.00	14.75
5/16	12.50	11.72	12.81	13.75	13.45	14.37	11.87	11.25	18.42
3/8	15.00	14.06	15.36	16.50	16.14	17.24	14.24	13.50	22.10
7/16	17.50	16.41	17.93	19.25	18.82	20.12	16.17	15.75	25.80
1/2	20.90	18.75	20.50	22.00	21.50	23.00	19.00	18.00	29.50
9/16	22.50	21.10	23.06	24.75	24.20	25.87	21.37	20.25	33.17
5/8	25.00	23.44	25.62	27.50	26.90	28.74	23.74	22.50	36.84
11/16	27.50	25.79	28.18	30.25	29.58	31.62	26.12	24.75	40.54
3/4	30.00	28.12	30.72	33.00	32.28	34.48	28.48	27.06	44.20
13/16	32.50	30.48	33.28	35.75	34.95	37.37	30.87	29.25	47.92
7/8	35.00	32.82	35.86	38.50	37.64	40.24	32.34	31.50	51.60
15/16	37.50	35.16	38.43	41.25	40.32	43.12	35.61	33.75	55.36
1	40.00	37.50	41.00	44.00	43.00	46.00	38.00	36.00	59.00

Weight of Metals. To Find Weight in Pounds.

Aluminium	cubic	inches	× 0.094
Brass	“	“	× 0.31
Copper	“	“	× 0.32
Cast-Iron	“	“	× 0.26
Wrought-Iron	“	“	× 0.28
Lead	“	“	× 0.41
Mercury	“	“	× 0.49
Nickel	“	“	× 0.31
Tin	“	“	× 0.26
Zinc	“	“	× 0.26

DIAMETERS, CIRCUMFERENCES, AREAS, SQUARES, AND CUBES.

Diameter in Inches.	Circumference in Inches.	Area in Square Inches.	Area in Square Feet.	Square, in Inches.	Cube, in Inches.
⅛	.3927	.0122	....	.0156	.00195
¼	.7854	.0490	....	.0625	.01563
⅜	1.1781	.1104	....	.1406	.05273
½	1.5708	.1963	....	.25	.125
⅝	1.9635	.3068	....	.3906	.24414
¾	2.3562	.4417	....	.5625	.42138
⅞	2.7489	.6013	....	.7656	.66992
1	3.1416	.7854	....	1.	1.
1⅛	3.5343	.9940	.0069	1.2656	1.42383
1¼	3.9270	1.2271	.0084	1.5625	1.95313
1⅜	4.3197	1.4848	.0102	1.8906	2.59961
1½	4.7124	1.7671	.0122	2.25	3.375
1⅝	5.1051	2.0739	.0143	2.6406	4.291
1¾	5.4978	2.4052	.0166	3.0265	5.3593
1⅞	5.8905	2.7611	.0191	3.5156	6.5918
2	6.2832	3.1416	.0225	4.	8.
2⅛	6.6759	3.5465	.0245	4.5156	9.5957
2¼	7.0686	3.9760	.0275	5.0625	11.3906
2⅜	7.4613	4.4302	.0307	5.6406	13.3965
2½	7.8540	4.9087	0340	6.25	15.625
2⅝	8.2467	4.4119	.0375	6.8906	18.0879
2¾	3.6394	5.9395	.0411	7.5625	20.7969
2⅞	9.0321	6.4918	.0450	8.2656	23.7637
3	9.4248	7.0686	.0490	9.	27.
3⅛	9.8175	7.6699	.0531	9.7656	30.5176
3¼	10.210	8.2957	.0575	10.5525	34.3281
3⅜	10.602	8.9462	.0620	11.3906	38.4434
3½	10.995	9.6211	.0668	12.25	42.875
3⅝	11.388	10.320	.0730	13.1406	47.634
3¾	11.781	11.044	.0767	14.0625	52.734
3⅞	12.173	11.793	.0818	15.0156	58.185
4	12.566	12.566	.0879	16.	64.

Diameters, Circumferences, Are

and Cubes.

Diameter in Inches.	Circumference in Inches.	Area in Square Inches.	Area in Square Feet.	Sq in I
4⅛	12.959	13.364	.0935	17.
4¼	13.351	14.186	.0993	18.
4⅜	13.744	15.033	.1052	19.
4½	14.137	15.904	.1113	20.
4⅝	14.529	16.800	.1176	21.
4¾	14.922	17.720	.1240	22.
4⅞	15.315	18.665	.1306	23.
5	15.708	19.635	.1374	25.
5⅛	16.100	20.629	.1444	26.
5¼	16.493	21.647	.1515	27.
5⅜	16.886	22.690	.1588	28.
5½	17.278	23.758	.1663	30.
5⅝	17.671	24.850	.1739	31.
5¾	18.064	25.967	.1817	33.
5⅞	18.457	27.108	.1897	34.
6	18.849	28.274	.1979	36.
6⅛	19.243	29.464	.2062	37.
6¼	19.635	30.679	.2147	36.
6⅜	20.027	31.919	.2234	40.
6½	20.420	33.183	.2322	42.
6⅝	20.813	34.471	.2412	43.
6¾	21.205	35.784	.2504	45.
6⅞	21.598	37.122	.2598	47.
7	21.991	38.484	.2693	49.
7⅛	22.383	39.871	.2791	50.
7¼	22.776	41.282	.2889	52.
7⅜	23.169	42.718	.2990	54.
7½	23.562	44.178	.3092	56.
7⅝	23.954	45.663	.3196	58.
7¾	24.347	47.173	.3299	60.
7⅞	24.740	48.707	.3409	62.
8	25.132	50.265	.3518	64.

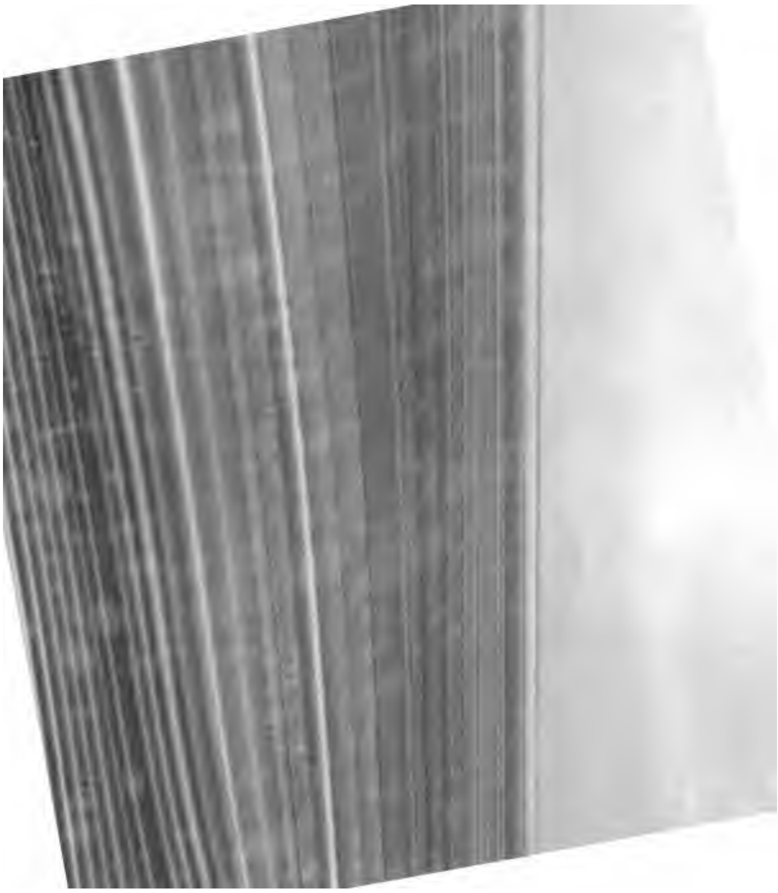
DIAMETERS, CIRCUMFERENCES, AREAS, SQUARES, AND CUBES.

Diameter in Inches.	Circumference in Inches.	Area in Square Inches.	Area in Square Feet.	Square in Inches.	Cube in Inches.
8⅛	25.515	51.848	.3629	66.0156	536.3770
8¼	25.918	53.456	.3741	68.0625	561,5156
8⅜	26.310	55.088	.3856	70.1406	587.4277
8½	26.703	56.745	.3972	72.25	614,125
8⅝	27.096	58.426	.4089	74.3906	641.6191
8¾	27.489	60.132	.4209	76.5625	669.9219
8⅞	27.881	61.862	.4330	78.7656	699.0449
9	28.274	63.617	.4453	81.	729.
9⅛	28.667	65.396	.4577	83.2656	759.7988
9¼	29.059	67.200	.4704	85.5625	791.4531
9⅜	29.452	69.029	.4832	87.8906	828.9746
9½	29.845	70.882	.4961	90.25	857.375
9⅝	30.237	72.759	.5093	92.6406	891.666
9¾	30.630	74.662	.5226	95.0625	926.8594
9⅞	31.025	76.588	.5361	97.5156	962.0968
10	31.416	78.540	.5497	100.	1000.
10⅛	31.808	80.515	.5636	102.5156	1037.9707
10¼	32.201	82.516	.5776	105.0625	1076.8906
10⅜	32.594	84.540	.5917	107.6406	1116.7715
10½	32.986	86.590	.6061	110.25	1157.625
10⅝	33.379	88.664	.6206	112.8906	1199.4629
10¾	33.772	90.762	.6353	115.5625	1242.2969
10⅞	34.164	92.885	.6499	118.2656	1286.1387
11	34.557	95.033	.6652	121.	1331.
11⅛	34.950	97.205	.6804	123.7656	1376.8926
11¼	35.343	99.402	.6958	126.5625	1423.8281
11⅜	35.735	101.623	.7143	129.3906	1471.8184
11½	36.128	103.869	.7270	132.25	1520.875
11⅝	36.521	106.139	.7429	135.1406	1571.0098
11¾	36.913	108.434	.7590	138.0625	1622.234
11⅞	37.306	110.753	.7752	141.0155	1674.5605
12	37.699	113.097	.7916	144.	1728.

TENSILE STRENGTH OF BOLTS.

Diameter of Bolt in Inches.	Area at Bottom of Thread.	At 7,000 lbs. per square inch.	At 10,000 lbs. per square inch.	At 12,000 lbs. per square inch.	At 15,000 lbs. per square inch.	At 20,000 lbs. per square inch.
½	.125	875	1,250	1,500	1,875	2,500
⅝	.196	1,372	1,960	2,350	2,940	3,920
¾	.3	2,100	3,000	3,600	4,500	6,000
⅞	.42	2,940	4,200	5,040	6,300	8,400
1	.55	3,850	5,500	6,600	8,250	11,000
1⅛	.69	4,830	6,900	8,280	10,350	13,800
1¼	.78	5,460	7,800	9,300	11,700	15,600
1⅜	1.06	7,420	10,600	12,720	15,900	21,200
1½	1.28	8,960	12,800	15,360	19,200	25,600
1⅝	1.53	10,710	15,300	18,360	22,950	30,600
1¾	1.76	12,320	17,600	21,120	26,400	35,200
1⅞	2.03	14,210	20,300	24,360	30,450	40,600
2	2.3	16,100	23,000	27,600	34,500	46,000
2¼	3.12	21,840	31,200	37,440	46,800	62,400
2½	3.7	25,900	37,000	44,400	55,500	74,000

The breaking strength of good American bolt iron is usually taken at 50,000 pounds per square inch, with an elongation of 15 per cent before breaking. It should not set under a strain of less than 25,000 pounds. The proof strain is 20,000 pounds per square inch, and beyond this amount iron should never be strained in practice.



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